Global Loss of Coastal Habitats
Rates, Causes and Consequences

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Offprint of Chapter

INTRODUCTION:

by

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THE ECOSYSTEMS PRESENT in boundaries between biomes typically rank amongst the most productive and diverse on the planet (McClain et al. 2003). The coastline, with about 300,000 to 1,000,000 km of length globally, represents the boundary between the two largest domains for life on Earth, the land and the oceans, and is home to highly productive and diverse ecosystems. In particular, marine coastal habitats include salt marshes, mangrove forests, coral reefs, seagrass meadows and algal beds that once occupied much of the global coastline, extending as a belt along the coastline from the bottom of the photic layer, the depth receiving sufficient light to allow the growth of marine primary producers, to the upper limit of the intertidal zone. Analysis of the irradiance fields of the coastal ocean has revealed that the area able to support these coastal habitats occupies about 30% of the global shelf (Gattuso et al. 2006). Coral reefs and mangrove forests are generally confined to tropical and subtropical coasts, with minimum seawater temperatures of about 20ºC, although mangroves occur in colder waters along the coast of Asia (e.g., northern Vietnam). Seagrass meadows occur across a broad latitudinal range and are only absent from Antarctica, while macroalgal beds are found on every coastline. Salt marshes occur on temperate coastlines, particularly those with a significant tidal range. Salt marshes and mangroves occupy the upper intertidal area, whereas seagrass and macroalgal beds extend from the subtidal to the lower intertidal and coral reefs grow in the subtidal zone.

Coastal habitats rank amongst the most productive in the world, with overall rates of primary production comparable to those of the rainforest (Cebrián and Duarte 1996). They are also important biodiversity hotspots supporting rich species assemblages. This renders them important habitats for biodiversity conservation, as they frequently harbor endangered species. Although coral reefs are credited with being oceanic analogs to the tropical forest, for the biodiversity they support, recent analyses have shown that other, less charismatic

◀ **Photo 1: Mangrove forest, Borneo.** Mangrove forests are highly productive ecosystems, rich in biodiversity, found along river deltas on tropical coasts.

Photo 2: *Cymodocea* meadows, Canary Islands. This fast-growing angiosperm, which advances along the seabed at a rate of several meters per year, forms highly productive ecosystems along the Atlantic and Mediterranean coasts.

coastal habitats, among them seagrass meadows, also shelter a wide range of endangered and threatened marine species, such as seahorses or dugongs, which outnumber seagrass species by a factor of 10 (Hughes et al. 2008). Hence conserving coastal habitats is a sound strategy for the conservation of many threatened marine species. In addition to their resident fauna, they serve as nursery grounds for numerous species that recruit in these habitats before going off to live their adult lives elsewhere. Many of these species are commercially important, so the rich biodiversity characteristic of coastal habitats is also a source of food for human populations around the world.

The high production of coastal areas also renders them important sites for carbon sequestration. Vegetated coastal habitats, particularly salt marshes, seagrass meadows, and mangrove forests, have recently been shown to sequester 111 Tg C year^{-1} in their sediments (Duarte, Middelburg, and Caraco 2005). This represents 50% of all carbon sequestration in ocean sediments, by habitats that together cover less than 2% of the ocean surface (Duarte, Middelburg, and Caraco 2005). Indeed coastal habitats contribute to stabilize sediments in the presence of wave energy. In addition, the complex canopies and structures they develop and the reef structures they form help to dissipate wave energy and shelter the shoreline from physical disturbances; a major, though largely unrecognized service that coastal habitats provide to society. Because of these and other important functions, such as nutrient cycling—likewise a product of their high production and metabolic rates—coastal habitats are acknowledged as ranking among the most valuable ecosystems on Earth. Coral reefs, mangrove forests, salt marshes, and seagrass meadows have been estimated to deliver the highest value, in terms of ecosystem services (US$[1992]6,000–19,000 ha^{-1}), of all natural ecosystems on the planet (Costanza et al. 1997). In comparison, the services provided by tropical forests were estimated to supply US$(1997)2,000 ha^{-1}.

The services society receives from ecosystems have become increasingly compromised, with human population growth and the associated pressures on the environment leading to the worldwide decline of key ecosystems, eroding biological diversity and ecosystem functions (e.g., Balmford, and Bond 2005). This is especially apparent in the coastal zone that is home to a large part of the global human population, of which 37% lives within just 100 km of the coastline. This proportion is growing, moreover, as a result of population growth and migration to these regions, with the result that seventy per cent of the world's megacities (> 1.6 million) are now located on the coastal strip (LOICZ 2002).

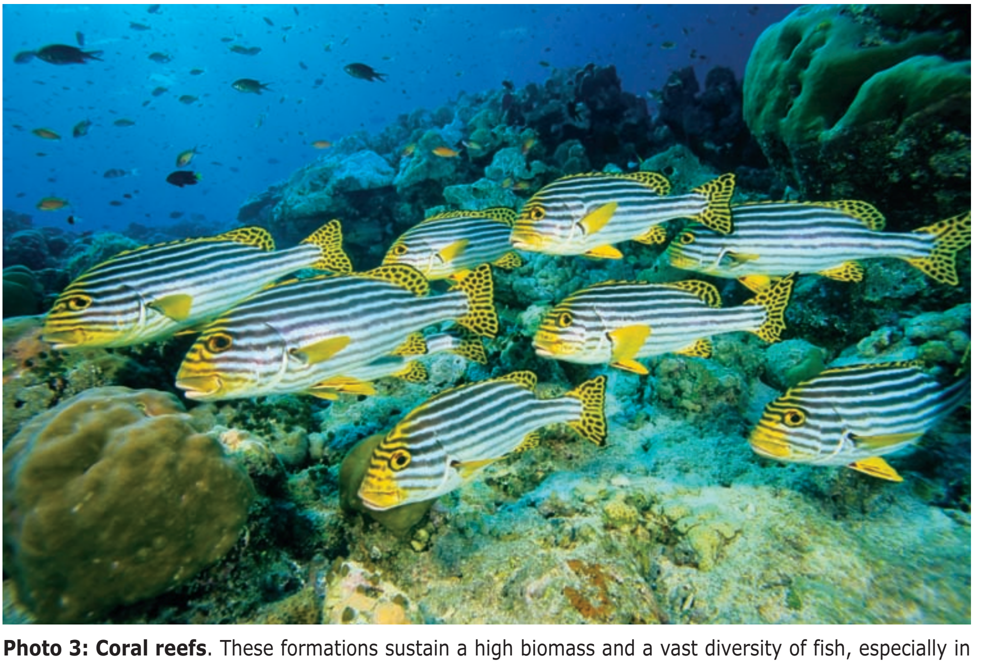

Photo 3: Coral reefs. These formations sustain a high biomass and a vast diversity of fish, especially in their unexploited state.

The ensuing anthropogenic pressures on coastal habitats have led to a sustained global loss of coral reefs, mangrove forests, salt marshes, and seagrass meadows over the past five decades. The global loss rate of threatened coastal ecosystems is estimated at 4-9% yr^{-1} for corals, a minimum of 1-2% yr^{-1} for salt marshes, 1-3% yr^{-1} for mangrove forests, and 2-5% yr^{-1} for seagrass meadows (Duarte et al. 2008), all of which exceed the global loss rate of tropical forests, estimated at 0.5% yr^{-1} (Achard et al. 2002). The drivers of these losses are multiple, including land reclamation, coastal development, excess sediment, nutrient and organic inputs—with the resulting spread of coastal hypoxia (Vaquer-Sunyer and Duarte 2008)—overfishing, mechanical damage by boats and fishing gear, logging, impacts from invasive species and intensive aquaculture, and the influence of climate change. These pressures do not act in isolation and, rather than delivering additive impacts, involve feedback processes and synergies that multiply their individual effects on coastal ecosystems.

The impacts of losses of coastal habitats are far reaching, since they not only erode biodiversity, but also reduce the provision of the valuable ecosystem functions associated with coastal ecosystems. The importance of these services can best be understood by reference to a key, but largely unrecognized function; the protection of coastal communities from natural disasters. This was dramatically illustrated in December 2004 when the large tsunami that struck Southeast Asia caused a much higher death toll in coastal villages devoid of mangrove protection than in those with preserved pockets of mangroves (Kathiresan and Rajendran 2005). It is also now recognized that the damage wreaked by Hurricane Katrina (August 2005) was exacerbated by the extensive loss of salt marshes in the Mississippi River delta (Tibbetts 2006).

One response to these events has been an effort to increase our understanding of the role of coastal habitats in delivering services to society, and of the causes and consequences of their loss. It is vital, however, that this understanding is accompanied by greater public awareness of the nature and dimension of the problem, in order to promote effective management and protect or restore the ecosystems under threat. Yet an analysis of publication effort and public awareness, as measured by news reports and stories in the worldwide media, reveals that the level of awareness is not correlated with the scientific effort, and that some habitats, particularly seagrass meadows, receive disproportionately less attention than more popular systems like coral reefs or tropical forests (Duarte et al. 2008). Indeed seagrass meadows tend to lack charisma and have been labeled the “ugly ducklings” of conservation efforts (Duarte et al. 2008). However the fact that even the “higher-

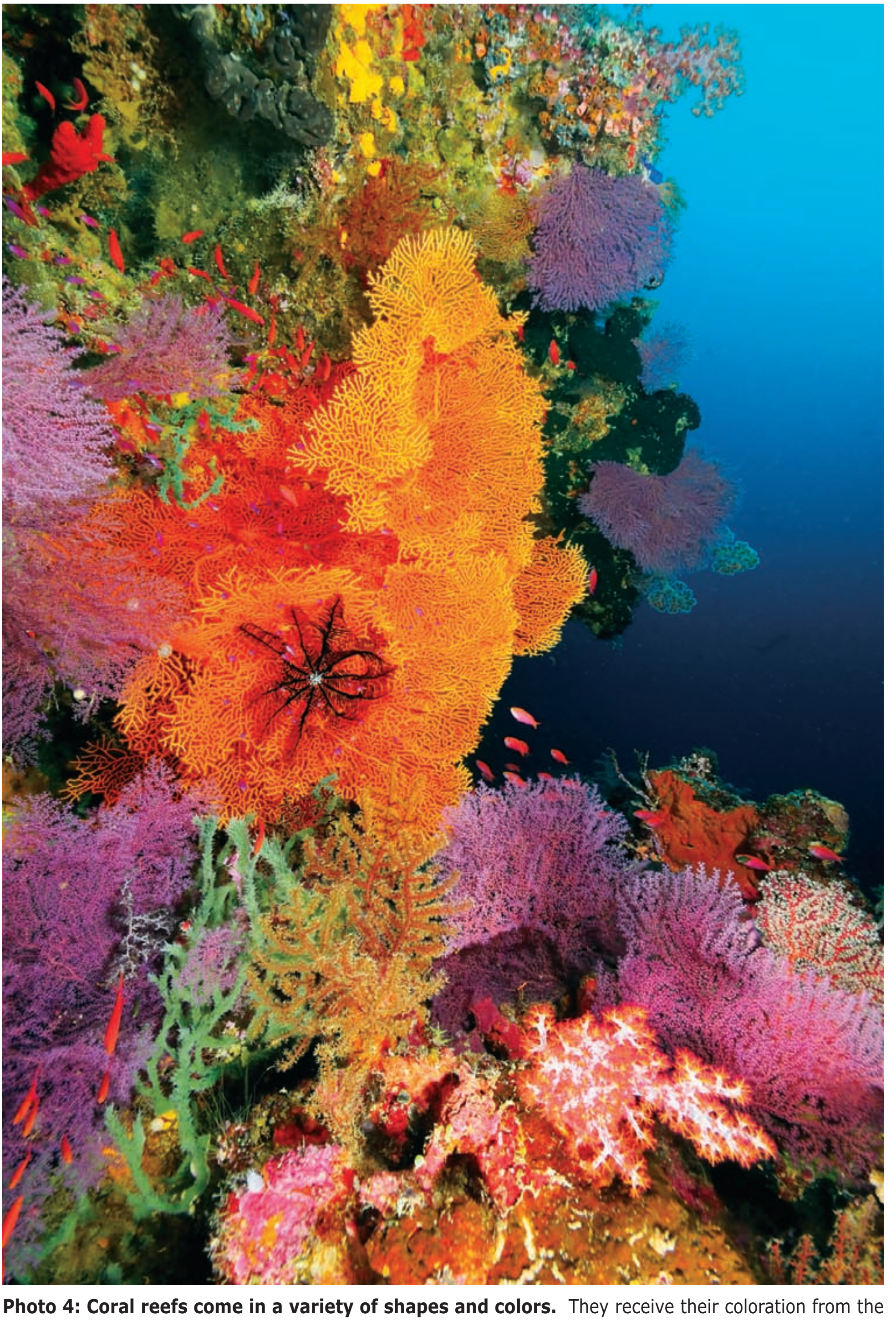

Photo 4: Coral reefs come in a variety of shapes and colors. They receive their coloration from the pigments of symbiotic algae living within their tissues.

profile" habitats, such as coral reefs, are still registering substantial losses shows how far away we are from engaging effective conservation support. Large-scale restoration efforts are possible for some coastal habitats, as demonstrated by the Vietnamese people's afforestation of the large mangrove forest of the Mekong Delta, following its mass destruction by the defoliating Agent Orange used by the U.S. Air Force during the Vietnam War (Stellman et al. 2003). But, aside from small-scale demonstration projects, the recovery of other coastal habitats, particularly seagrass meadows and coral reefs, may involve timescales ranging from decades to millennia. Hence a conservative approach to the management of coastal habitats, emphasizing the prevention of losses, must prevail over approaches based on the perspective of compensatory actions to restore damaged ecosystems.

This volume seeks to increase awareness of the loss of coastal habitats by providing detailed analyses, global in scope, of the scale of such losses and their causes and consequences for individual systems. Hence chapters are devoted to changes in the seagrass habitat at a global scale (Dennison) and in the Mediterranean Sea (Marbà), losses in salt marsh and mangrove ecosystems (Valiela et al.), and those affecting coral reefs (Hughes). Room is also found for a detailed analysis of the eutrophication of the coastal ocean (Nixon and Fulweiler), a major driver of the deterioration and subsequent loss of coastal habitats. Its origins lie in the talks delivered at the BBVA Foundation–Cap Salines Lighthouse Coastal Research Station Colloquium held in Madrid on October 10, 2007, which also lends its title to the present volume. This Colloquium was the third in a series addressing issues in marine ecology and biodiversity, with previous editions dedicated to scientific and technological challenges in the exploration of marine biodiversity and the impacts of climate warming on polar ecosystems respectively. Colloquium presentations can be viewed in full on the BBVA Foundation website[1], which provides a useful complement, particularly for teaching purposes, to the chapters of this book.

The reviews undertaken in these chapters converge to demonstrate high loss rates of coastal habitats, driven by the rapid occupation of the coastline by humans, increased inputs of nutrients to coastal ecosystems, and the emerging impacts of climate change. While the occupation of the coastline by infrastructures and eutrophication are processes unfolding locally, their occurrence is sufficiently widespread as to constitute a global phenomenon. Climate change, which comes on top of these pressures to deliver the *coup de grâce* to already

[1] http://www.fbbva.es/TLFU/tlfu/ing/areas/medioamb/conferencias/fichaconfe/index.jsp?codigo=653

Photo 5: Salt marshes. These habitats have a complex drainage structure with plant life differentiated into levels, from angiosperms at the upper tidal limit to clumps of seaweed at the bottom.

stressed coastal habitats, operates through three main forces: warming, affecting the physiological processes and life-history patterns of marine species; sea level rise, with the associated coastal erosion; and the increase in CO_2 concentration, causing the acidification of seawater, which may enhance photosynthetic rates but at the same time impact negatively on calcifying organisms. One important thread running through the book is the evidence that the impacts of climate change are not gradual and incremental. Rather there are thresholds of climate forcing beyond which impacts on organisms and ecosystems increase abruptly, in some cases threatening catastrophic mortality, as has been demonstrated for coral reefs (Hughes) and seagrass meadows (Marbà). There is, therefore, a need to manage these risks conservatively, in the knowledge that we cannot afford to cross those thresholds, with the loss of biodiversity and valuable ecosystem services that would certainly ensue. I trust that the chapters presented in this book will provide a useful departure point for those eager to learn about the scale of the threats facing coastal habitats, and for those whose job it is to manage and conserve them.

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