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Saving Venice: Engineering and ecology in the Venice lagoon

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Abstract

This paper describes some of the challenges of sustainability, and shows how they are manifested in coastal environments. It reviews the problems facing Venice and its lagoon, as a particularly interesting and complex example, and describes the technological, environmental, and scientific actions taken to address the problems of sustainability. Specifically, the actions and interdisciplinary research supporting management of the Venice lagoon environment are discussed, with a particular focus on the sediment. Conclusions are drawn regarding the integration of science, technology, and the environment, including the interactions of industry, the international scientific community, and governments.

Keywords: Venice; Lagoon; Sediment management; Sustainability; SIOSED

1. Introduction

1.1. The challenge of sustainability

The impact of human industrial development on natural ecosystems is increasingly evident around the world in many forms. Species are becoming extinct as a result of human encroachment on habitats. Fossil fuel consumption has increased greenhouse gas emissions resulting in rising sea levels, increasing atmospheric temperatures, and melting glaciers. Once-prosperous commercial fisheries have collapsed following the introduction of industrial fishing ships and refrigeration. Industrialized countries impact the natural environment at rates far in excess of long-term sustainability, and developing countries have yet to meet the basic needs of many of their inhabitants. Clearly, we need to find pathways to the future that allow environmental sustainability as well as economic and social prosperity.

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1.2. Sustainability in coastal ecosystems

The challenges of sustainability are not limited to any particular geographic area or to any social or economic group. However, coastal ecosystems represent one of the clearest interfaces between human societies and the environment. Whether in an ancient city like Venice, Italy, or relatively new city like San Diego, California, we are now witnessing the results of human activities that were undertaken during a period of time when nature was presumed to be limitless, resilient, and available for human exploitation. We have only recently begun to acknowledge that our planet is a finite, closed system whose resources must be nurtured and recycled. This, in turn, has made us realize that successful environmental management strategies must recognize the complex interdependence of human and non-human components of the natural system and strive for long-term sustainability. Whereas, once it was considered acceptable to dump toxic waste into the ocean, assuming the contaminants would be sufficiently diluted to be rendered harmless, now such practices are considered illegal and immoral.

By employing a broad range of expertise from the natural and social sciences, engineering, and the humanities, we have the potential to develop science-based, integrated, decision-support tools that enable us to describe and anticipate interconnections and impacts among the various aspects of a particular ecosystem. The global community of knowledge also enables us to draw on local, indigenous expertise and knowledge and combine it with lessons from other communities whose experiences might be applicable. This allows decision makers to apply the standards and values of their constituents while building on a knowledge base that is, in principle, global.

The historic city of Venice, Italy, and its lagoon, represent a fascinating and complex window into the challenges of sustainability: meeting today's needs without compromising the ability of future generations to meet their own needs [1]. The problem: the frequency of flooding in Venice is increasing. Managing the Venice lagoon in a way that protects the city from the floods while permitting a functional lagoon ecosystem to thrive is an excellent example of the dramatic interactions of nature, science, and technology made even more challenging by the historical and political context in which the problems and solutions are unfolding. With more than 50 different national governments in the last century of Italian politics, and with sometimes different political parties in power in Venice and in Rome, mounting a complex program to address the threats to Venice and its surrounding areas is a major political and organizational challenge as well as a difficult science and engineering problem.

2. About lagoons

Lagoons are inland bodies of water nourished by both fresh and saltwater inputs. Lagoons are always coastal and estuarine, located at the confine between freshwater and marine ecosystems. Because of this, lagoons are important structures from an ecological standpoint, sustaining a diversity of species. Lagoons are typically shallow, rich in nutrients, and associated with high productivity. They host abundant fauna and flora that are sometimes of socioeconomic importance, either on a permanent or temporary basis, even if the organism only takes advantage of shelter areas of the lagoon for reproduction purposes [2,3].

The environment in a lagoon is heterogeneous. There is, for example, a land-to-sea salinity gradient and variability of the bottom-floor profile following sediment transport and accretion by wind and/or tide-driven water circulation. Diversity in the geomorphology of a lagoon bottom provides diversity in habitats and niches, and these in turn support greater biodiversity. Thus, a lagoon's ecology depends on a delicate dynamic balance between multiple factors, including water circulation and input, sediment transport, geochemistry of sediment particles, and the life history, biology, and ecology of endemic species [2,4].

Sediment in lagoons is often highly contaminated because extensive human settlement is typically sited on lagoons; lagoons are also the end reservoir of contaminants transported by rivers [5]. Contaminants, whether chemicals like metals and hydrocarbons, or pathogenic microbes and viruses, thus end up in sediment where they are trapped and accumulate over time. However, they can be released and made available to the local ecosystem in response to changes in surrounding physical and chemical conditions [5,6]. These changes can be natural and inherent in the ecosystem, or induced by anthropogenic activity. In any case, because contaminants rendered available can be toxic to the local fauna and flora, it is essential to understand and