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Mini-review

Ecological roles of zoosporic parasites in blue carbon ecosystems

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ABSTRACT

Pathosystems describe the relationships between parasites, hosts and the environment. Generally these systems remain in a dynamic equilibrium over time. In this review we examine some of the evidence for the potential impacts of change in dynamic equilibrium in blue carbon ecosystems and the relationships to the amount of stored carbon. Blue carbon ecosystems are marine and estuarine ecosystems along the coasts. Virulent pathogens can be introduced into ecosystems along with non-native hosts. Alteration of environmental conditions, such as temperature, pH and salinity, may cause parasites to dominate the pathosystems resulting in significant decreases in productivity and population sizes of producer hosts and in changes in the overall species composition and function in these ecosystems. Such changes in blue carbon ecosystems may result in accelerated release of carbon dioxide back into the ocean and atmosphere, which could then drive further changes in the global climate. The resiliency of these ecosystems is not known. However, recent evidence suggests that significant proportions of blue carbon ecosystems have already disappeared.

Introduction

Conservation in blue carbon ecosystems

Recently the International Working Group on Coastal Blue Carbon concluded that coastal carbon deposits need to be considered in national emission inventories, because continued degradation of blue carbon ecosystems could result in further increases in carbon dioxide emissions into the atmosphere (Copertino and Da, 2011). Blue carbon ecosystems are marine and estuarine ecosystems which occur along the coasts of all continents and which contain populations of highly productive species of producers such as mangroves, seagrasses, large seaweeds, phytoplankton and corals, and significant carbon sinks.

Sediments in salt marshes, seagrass meadows, mangrove forests and subtidal benthic ecosystems are known to provide

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important carbon sinks where refractive carbon is buried for long periods (Fourqurean et al., 2012). In particular, seagrass meadows are considered among the most productive ecosystems on earth, and the carbon sink capacity of seagrass meadows is exceptional (Orth et al., 2006; Duarte et al., 2010, 2013). Seagrasses support high biodiversity habitats and account for approximately 20 % of the total carbon sequestration in marine sediments.

The amount of organic carbon stored in healthy living seagrass biomass is estimated at 2.52 Mg C ha^{-1} on average, much of which is buried in the soil as rhizomes and roots (Fourqurean et al., 2012). If pathosystems are not in equilibrium and disease results in the death of seagrass populations, much of this carbon could be released into the ocean and the atmosphere. Seagrass meadows currently are estimated to bury approximately 27.4 Tg C yr^{-1} in total globally. If all of the organic carbon in seagrass biomass and the top metre of soils were to be remineralized, present rate of loss could result in release of up to 299 Tg C yr^{-1} (Fourqurean et al., 2012).

According to Copertino and Da (2011) the carbon sinks in many of these ecosystems presently have insufficient environmental protection. In fact, many blue carbon ecosystems are disappearing at a rapid rate (Copertino and Da, 2011). For example, Waycott et al. (2009) estimated that 29 % of all known seagrass area in the world disappeared between 1879 and 2009, and the rate of loss is accelerating. Some of this loss is due to total habitat destruction, while other losses are due to environmental factors. The significance of the rapid rates of loss of seagrass populations was highlighted again very recently by Bockelmann et al. (2013). Seagrass populations are particularly sensitive to increasing anthropogenic influences in coastal ecosystems (Orth et al., 2006), but environmental changes are seriously impacting the distributions and population densities of many other marine species as well (Schiel et al., 2004; Polovina et al., 2011). Examples of endangered ecosystems near Sydney Australia are shown in Figs 1–3.

In this review we consider the potential roles of zoosporic parasites in reduction in size of populations of producers and subsequent loss of carbon sinks in marine ecosystems. We use the pathosystems model for analysis of host-parasite dynamics. We discuss examples of specific hosts infected by zoosporic parasites. Finally we discuss the effects of physical factors and introduction of non-native species on host-parasite dynamics.

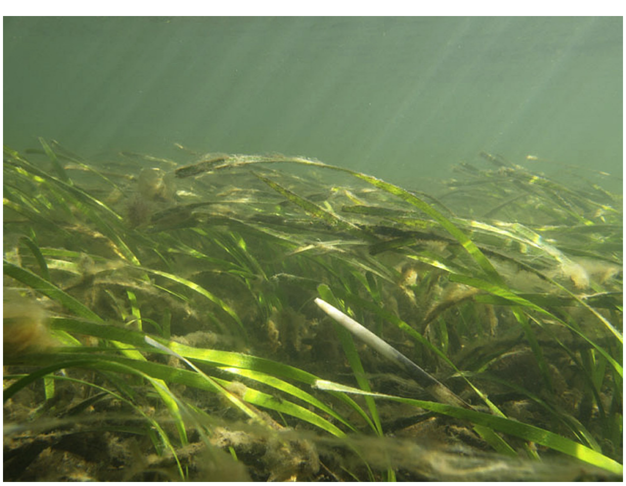

Fig 1 – Botany Bay. An endangered blue carbon ecosystem near Sydney, Australia. Seagrass communities are visible under water in a shallow region of the bay.

Zoosporic parasites

Parasites include a large number of species, play critical roles in ecology and often face extinction when the structure and function of ecosystems change (Dobson and Hudson, 1986; Lafferty et al., 2008; Nichols and Gómez, 2011). Nevertheless, parasitism is a significant biotic factor which is rarely considered in reviews of the global environmental crisis (Nichols and Gómez, 2011). In particular, parasites are thought to play important roles in the carbon cycle, especially the microbial loop, in all aquatic ecosystems but research on this topic has been limited (Sime-Ngando, 2012). Zoosporic parasites are eukaryotic microorganisms (microparasites) which propagate by motile (flagellated) zoospores. In this paper we focus on some of the important zoosporic parasites (consumers) of populations of seagrasses and macro-algae (producers) in blue carbon ecosystems, their roles in population declines of dominant species and their potential roles in disease and population dynamics (1) from the perspective at the time of the third International Congress of Plant Pathology (Andrews, 1979) and (2) from the present perspective considering continuous global climate change, as adopted by the International Working Group on Coastal Blue Carbon (Copertino and Da, 2011). Some examples of zoosporic parasites in the Chytridiomycota, Oomycota, Hyphochytriomycota, Labyrinthulomycota and Phytomyxea are included.

Pathosystems

Robinson (1976) introduced the concept of a pathosystem for the study of disease in terrestrial plants. A pathosystem is defined as the component of an ecosystem which involves parasitism. At the third International Congress of Plant Pathology in Munich, Andrews (1979) suggested that many of the concepts used in the study of the pathology of terrestrial plants be introduced into the study of the role of disease in marine seaweed ecosystems. In particular, Andrews (1979) proposed the use of the "pathosystem" concept in marine ecology. Here we use the pathosystems approach to analyse host-parasite relationships for hosts (producers: flowering plants, macroalgae and phytoplankton) and zoosporic parasites (consumers: true fungi, heterotrophic stramenopiles and protists) in marine ecosystems and relate this to the potential loss of blue carbon stores.

Pathosystems are dynamic systems involving populations of hosts and parasites (Robinson, 1976). A dynamic system can remain stable only if it retains system balance or equilibrium which is achieved by systems controls. Systems controls involve communications between the component parts of the system. We would expect populations of parasites and hosts in pathosystems to remain in dynamic equilibrium as long as the systems controls are operating correctly. If the systems controls cannot operate, the equilibrium cannot be maintained, and relative