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Impacts of climate change on submerged and emergent wetland plants☆

Frederick T. Short[a,*], Sarian Kosten[b], Pamela A. Morgan[c], Sparkle Malone[d], Gregg E. Moore[e]

[a] University of New Hampshire, Department of Natural Resources and the Environment, Jackson Estuarine Laboratory, 85 Adams Point Road, Durham, NH 03824, USA
[b] Radboud University, Institute for Water and Wetland Research, Aquatic Ecology and Environmental Biology Department, Heyendaalseweg 135 6525 AJ Nijmegen, The Netherlands
[c] University of New England, Department of Environmental Studies, Biddeford, ME 04005, USA
[d] USFS Rocky Mountain Research Station, 240 W. Prospect Road, Fort Collins, CO 80526, USA
[e] University of New Hampshire, Department of Biological Sciences, Jackson Estuarine Laboratory, 85 Adams Point Road, Durham, NH 03824, USA

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ABSTRACT

Submerged and emergent wetland plant communities are evaluated for their response to global climate change (GCC), focusing on seagrasses, submerged freshwater plants, tidal marsh plants, freshwater marsh plants and mangroves. Similarities and differences are assessed in plant community responses to temperature increase, CO_2 increase, greater UV-B exposure, sea level rise and other expected environmental alterations associated with GCC. Responses to most climate change variables are more similar within submerged plant communities, marine or freshwater, than between submerged vs. emergent plant communities. The submerged plants are most affected by temperature increases and indirect impacts on water clarity. Emergent plant communities (marshes and mangroves) respond most directly to climate change related hydrological alterations. Wetland plant communities overall appear to be adversely impacted by all climate change variables, with the exception of increased CO_2 in the atmosphere and the oceans, which in most cases increases photosynthesis. Effects of GCC on all these communities have already been seen with many others predicted, including: shifts in species composition, shifts in range and distribution, and declines in plant species richness. Other effects are associated with specific community types, e.g., salt marsh habitat lost to mangrove incursion, and decreases in submerged macrophyte coverage in lakes and estuaries, exacerbated by eutrophication. Sea level rise poses threats to all aquatic plant community types in the vicinity of the oceans, and changes in weather patterns and salinity will affect many. Overall, losses are likely in all these wetland plant communities yet their species can adapt to GCC to some degree if well managed and protected.

1. Introduction

The wetlands evaluated here for their response to global climate change include submerged and emergent plant communities, ranging from marine to freshwater environments and including seagrasses, submerged freshwater plants, tidal marshes, freshwater marshes and mangroves. Most of these macrophyte communities are distributed in both tropical and temperate regions around the world, the exception being mangrove forests, which are restricted to the tropics (Tomlinson, 1986). Characterized by regular, seasonal, or occasional inundation, their health and survival is influenced by changes on adjacent land as well as adjacent and surrounding waters. Global climate change is likely to have greater and more immediate effects on wetland ecosystems than many habitats that are restricted to either terrestrial or oceanic environments. In developed areas, these plant communities are already stressed, sometimes to a great degree, by direct human activity; the indirect impacts of climate change will exacerbate existing stressors (Keddy, 2000).

The International Panel on Climate Change (IPCC, 2013; Pachauri et al., 2014) provides strong evidence that for the last three decades, globally averaged combined land and ocean surface temperatures

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* Corresponding author.
E-mail address: fred.short@unh.edu (F.T. Short).

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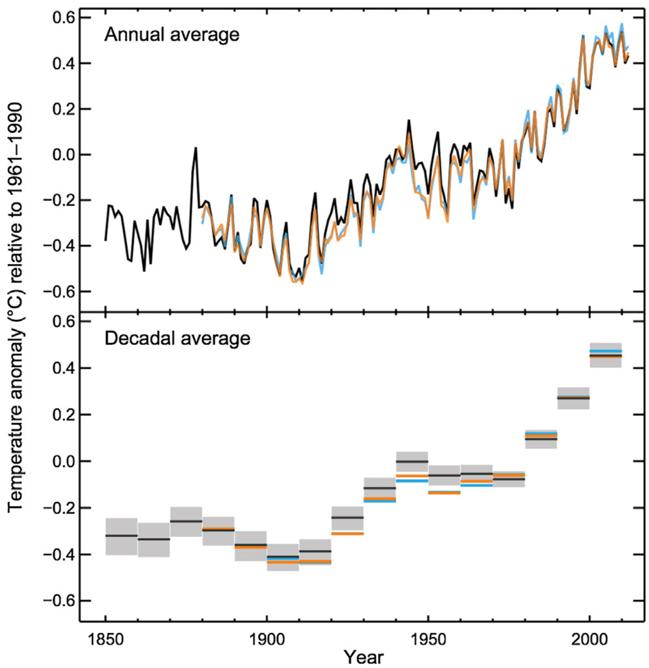

Fig. 1. Observed global mean combined land and ocean surface temperature anomalies, from 1850 to 2012 from three data sets. Top panel: annual mean values. Bottom panel: decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961–1990 (with permission, figure and legend taken from figure SPM.1 (a) from IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK and New York, USA.

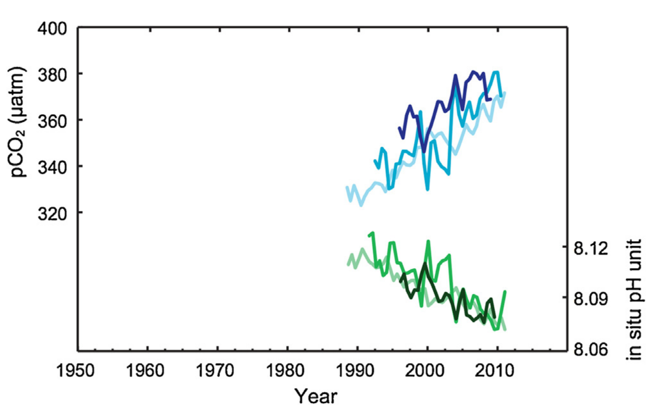

Fig. 2. Multiple observed indicators of a changing global carbon cycle: partial pressure of dissolved CO_2 at the ocean surface (blue curves) and in situ pH (green curves), a measure of the acidity of ocean water. Measurements are from three stations from the Atlantic (29°10′N, 15°30′W—dark blue/dark green; 31°40′N, 64°10′W—blue/green) and the Pacific Oceans (22°45′N, 158°00′W—light blue/light green). (with permission, figure and legend taken from Figure SPM.4 (b) from IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)] Cambridge University Press, Cambridge, UK and New York, USA. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

have been successively higher than any prior decade since the first records in 1850 (Fig. 1). Ocean temperatures by 2100 are predicted to increase 2 to 4 °C due to greenhouse gas effects (Pachauri et al., 2014). Atmospheric carbon dioxide concentrations (Fig. 2) have increased by over 40% since the Industrial Revolution (Pachauri

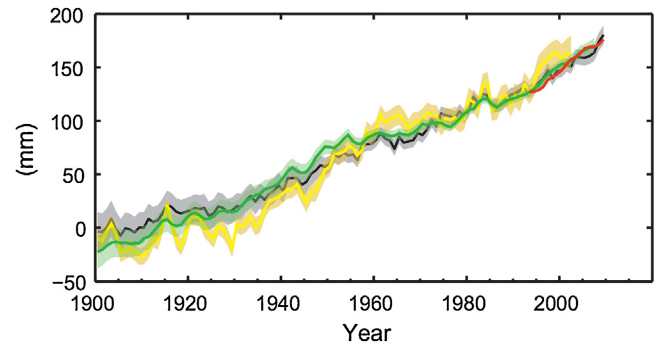

Fig. 3. Multiple observed indicators of a changing global climate: global mean sea level relative to the 1900–1905 mean of the longest running dataset, and with all datasets aligned to have the same value in 1993, the first year of satellite altimetry data. All time-series (coloured lines indicating different data sets) show annual values, and where assessed, uncertainties are indicated by coloured shading (with permission, figure and legend taken from figure SPM.3 (d) from IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK and New York, USA (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

et al., 2014). Assessments show a sea level rise of 17–32 cm over the past 100 years; now, worst-case projections predict sea level rise (SLR) rates of 1.6 cm yr^{-1} by 2100 (Pachauri et al., 2014) equivalent to a 1.9 m sea level increase over the next 100 years (Fig. 3). Other factors including changes in precipitation, salinity, and UV-B are also connected to climate change and will differentially affect various wetland plant communities.

The objectives of our paper are to review the pertinent recent literature and, from it, summarize the impacts to date of global climate change on wetland plants as well as projecting possible future impacts. Our approach is to assess the major submerged and emergent plant communities, considering the effects of rising temperature, increased CO_2, increased UV-B radiation, salinity changes, and sea level rise on their typical species.

The plant communities are ordered on an immersion gradient, from fully submerged salt and freshwater species to emergent salt and freshwater marsh species and finally, mangrove forests.

2. Seagrasses

Seagrasses are rooted marine submerged flowering plants that inhabit the world's coastal oceans and provide numerous ecosystem services to these waters and beyond, including filtration, primary production, and habitat and food for fish and wildlife. They are found on the tropical, temperate, and sub-arctic shallow coastal margins of all continents except Antarctica. Seagrasses support food webs of importance to humans and are critical food for endangered sea turtles and sirenians. These plants are declining worldwide by about 7% per year and "...global climate change is predicted to have deleterious effects on seagrasses and is emerging as a pressing challenge for coastal management" (Waycott et al., 2009).

2.1. Temperature

Seagrasses are strongly influenced by water temperature, which affects plant physiological processes, growth rates, and reproduction patterns, and determines the geographic distribution of species based on their temperature tolerances (Short and Neckles, 1999). While seagrass shoot mortality rates have been shown to increase with rising water temperatures (Díaz-Almela et al., 2009; Oviatt,