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Effects of Elevated CO_2 on Wetland Ecosystems

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Anthropogenic activities have increased the concentration of atmospheric CO_2 from about 280 parts per million (ppm) at the beginning of the industrial revolution to 369 ppm at the present time. Future estimates of atmospheric CO_2 concentration for the year 2050 range between 450 ppm and 600 ppm. More than two decades of study on the effects of CO_2 enrichment have greatly improved our understanding of plant responses such as net primary productivity, species abundance, community composition and soil respiration (root plus microbial respiration) in terrestrial ecosystems. In addition, the chemical and physical composition of plant material and decomposability of plant litter have drawn much attention. Many studies have suggested that elevated CO_2 may increase primary production in terrestrial ecosystems in the short-term, but such response may not be prolonged due to nutrient deficiency.Unlike terrestrial ecosystems, however, little is known about how wetland ecosystems will respond to elevated CO_2 conditions. As wetlands play a key role in global biogeochemical cycles, responses of wetlands to future global climatic changes are of great importance. For example, any modifications of wetland biogeochemistry by elevated CO_2 may affect wetland functions of water purification, carbon storage, greenhouse gas emission, etc. If primary production increases with elevated CO_2 in wetlands as suggested in certain terrestrial ecosystems, this may increase a carbon sink. However, if other responses (e.g., greenhouse gas emission and DOC leaching) are dominant, global warming may be accelerated by changes in wetland processes.To address this issue, we 1) summarized the responses of primary production, soil respiration, soil enzyme activities, nutrients in soil, and methane flux to elevated CO_2 using previous reports, and 2) conducted manipulation experiments using Solardomes facility (greenhouse) or indoor CO_2 chambers. Responses of wetland plants to elevated CO_2 were very diverse and species-specific. In addition, experimental duration and facilities seemed to interfere with the results of experiments. As such, our prediction with current knowledge on carbon storage of wetlands in the future environment is highly inaccurate. However, general patterns were revealed in relation to DOC release and CH4 emission. Elevated CO_2 increased root exudates into wetland soils, resulting in higher DOC concentration in pore-water. This is believed to activate methanogenesis in wetlands, and consequently increase methane efflux into the atmosphere from wetlands. These results suggest that a large carbon pool contained in wetlands may move into atmosphere or aquatic ecosystems in the future.We also measured enzyme activities in wetlands exposed to elevated CO_2 to elucidate impacts on nutrient cycling. No changes in carbon-mineralizing enzymes (-glucosidase and phenol oxidase) were found, which is attributed to an increase in easily decomposable carbon supply into wetland soils. In contrast, nitrogen- or phosphorus-mineralizing enzymes (phosphatase and N-acetylglucosaminidase) exhibited diverse responses by elevated CO_2. The diverse responses appeared to be related to nutrient availability in each system.Based on those findings, we suggest following research topics for the future studies. Firstly, longer-term studies in wetlands are needed to detect any acclimation observed in terrestrial studies. Secondly, multiple interacting variables should be considered simultaneously, since global climatic changes imply multi-layered environmental changes. For example, water level changes caused by alteration in precipitation patterns or temperature increases may mask or enhance any impacts caused by elevated CO_2. Thirdly, other components (e.g., algae or epiphyte) should be incorporated into systems rather than considering vegetation and microbes only, which has been a general approach. Fourthly, nutrient enrichment, nitrogen in particular, should be reflected upon CO_2-related studies in wetlands. The reasons are that many wetlands are expected to receive much larger amount of nitrogen through atmospheric deposition and non-point pollution, and that nitrogen is one of the most substantial modifiers for the effects of elevated CO_2. Finally, shifts in microbial communities under elevated CO_2 conditions have rarely been assessed, which is a critical step to have a better understanding.