Introduction

SPECIAL ISSUE
Fire and Water: New Perspectives on Fire's Role in Shaping Wetland Ecosystems

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ABSTRACT

This special issue of *Fire Ecology* is dedicated to furthering scientific understanding of the role fire plays in the development and functioning of wetland ecosystems. While not initially intuitive, the concept of fire exerting significant influence on how wetland environments function has only recently become a prominent topic of discussion among researchers, although it has been recognized by the management community for some time. This new interest in determining how large scale disturbances modulate ecological processes in wetlands led to a series of invited talks at a Fire in Wetlands session during the 9th International Association for Ecology (INTECOL) meeting in Orlando, Florida, USA, in 2012. The collection of work presented here is the product of that special session, and includes research covering diverse topics such as fire effects on wetland biogeochemistry, vegetation community structure, and wildlife dynamics. Managers' perspectives, while presented in multiple talks during the INTECOL session, are captured here in discussions of the management implications of the research presented. This introduction summarizes each of the papers included in this special issue and is organized into topics of biogeochemistry, vegetation, community dynamics, and wildlife dynamics. The summarizing comments include key messages for management and future directions for research on fire in wetlands.

Keywords: biogeochemistry, fire, hydrology, prescribed burn, vegetation dynamics, wetlands, wildlife

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The concept of fire shaping the wetland environment has become a prominent topic of discussion among wetland ecologists, managers, and restoration scientists. A database search for published peer-reviewed literature using "fire and wetlands" either as keywords or in the title or abstract resulted in 443 articles. Of these, 229 (approximately 50%) mentioned

fire as a potential causative agent for a result or observation. A majority of these papers speculated on a specific fire event or fire history as being related to observations. Another 77 papers directly addressed the role of fire in wetland ecosystem functioning with respect to specific aspects of wetland biota, while 36 other papers addressed geomorphology and physical processes within wetlands that are influenced by fire. The remaining 101 papers were not directly related to fire as an ecological driver in wetlands, but rather invoked the use of terminology captured in the search. For example, papers dealing with the fire salamander (*Salamandra salamandra*), a common European wetland amphibian, or fire flag, a common name for *Thalia geniculata* (L.), a wetland plant found throughout the tropics and subtropics, were also captured in this broad search. The relative scarcity of published works that investigate the role of fire in shaping wetland ecosystems indicates a need for increased attention from the scientific community.

Wetlands are recognized as globally important ecosystems for sequestration of carbon, transformation of nutrients, and as centers of diversity for aquatic organisms and as oases for terrestrial organisms. Fire is a natural and integral component of many wetland ecosystems (similar to grasslands) where burns maintain an herbaceous-dominated community. Fire also dictates the balance and cycling of nutrients, and thereby serves as a potent catalyst and limit to system production. Climate change, including changes to rainfall, temperature, and salinity, is expected to result in altered fuel conditions and therefore fire frequency, with wetlands being particularly vulnerable to hydrologic changes. Much of our understanding of current and future wetland functions hinges on increasing our knowledge of fire as an ecological driver in these sensitive ecosystems.

This recent interest in determining how large scale disturbances modulate ecological processes in wetlands led wetland researchers and managers to assemble a series of invited talks for a special "Fire in Wetlands" symposium during the 9th International Association for Ecology (INTECOL) meeting in Orlando, Florida in June, 2012. The collection of research in this issue is a product of that symposium, covering diverse topics including fire influence on microbial scale biogeochemistry, fire effects on vegetation community structure and landscape patterning, and fire's role in wildlife dynamics. Each of these topics has important consequences for informing management decision-making, as many of these wetlands are managed and/or restored using prescribed burning to simulate historical wildfire regimes.

Even at the scale of microorganisms, fire has a profound effect on the chemistry and biotic communities of wetlands. This is perhaps one of the least studied aspects of fire ecology, but also one of the most crucial as biogeochemical processes regulate nutrient cycling, productivity, and greenhouse gas emissions in these systems. In wetlands, the effect of fire on biogeochemical processes is not always predictable. For example, in this issue, Liao *et al*. demonstrate a pronounced stimulation of microbial enzymes and available soil nitrogen levels following a prescribed burn in the phosphorus (P) limited southern Everglades of Florida, USA. In the same ecosystem, Medvedeff *et al*. further demonstrate how fire both stimulated and suppressed carbon related enzymes, leading to variable responses in production of greenhouse gases (CO_2 and CH_4). Much of these differences are attributed to the type and abundance of combustion residues (ash or char) which may act as both source of nutrients (N and P) or carbon.

The role of fire has traditionally been viewed as a significant driver in upland ecosystems with respect to vegetation dynamics (Wade *et al.* 1980), and as such, fire can serve both as a positive or negative effect on vegetation community expansion (Lockwood *et al.* 2003) or species composition (Osborne *et al.*

2009) in wetland systems. In this issue, Ruiz *et al*. describe how fire in combination with hydrology can instigate a negative effect on tree islands, causing contraction in their spatial extent or, in extreme cases, loss of this sensitive community from the Everglades landscape. Conversely, Gagnon *et al*. report on the positive effects of fire on persistence and resilience of *Arundinaria gigantea* Walter (Muhl.), a bamboo native to the southeastern United States, following combined windstorm and fire disturbances. Smith *et al.* report on several sites in the coastal Everglades where fire is a significant driver in the expansion of mangroves into herbaceous marsh areas, especially those dominated by dense emergent macrophytes.

Fire can play a significant role in the dynamics of wildlife in wetlands through modification or maintenance of vegetation communities and thus habitat (McWilliams *et al.* 2007). Fire can also bring about rapid shifts in habitat that can have positive or negative effects on wildlife (Brennan *et al.* 2005). In this issue, Venne and Frederick report that wading birds are likely attracted to recently burned marsh areas due to more efficient feeding after the removal of dense vegetation. Conversely, Gorman *et al*. argue that the reticulated flatwoods salamander (*Ambystoma bishopi*) relies on fire to remove mid canopy vegetation and promote dense groundcover habitat necessary for reproduction. Gorman *et al.* also recognize the inherent value of such findings to the management of this endangered species, a consequence that resounds across much of the research presented in this issue.

Successful management of wetland ecosystems often necessitates the use of prescribed fire or a mechanical proxy to maintain native habitats (Lodge 2012). With projected climate change impacts to wetlands, the need for scientifically supported fire management strategies is increasing. To this end, Duever and Roberts present a conceptual ecological succession model synthesizing decades of investigation into the effects of hydrology and fire on South Florida vegetation communities. These types of succession models are useful and often-requested tools for regional managers as they enable predictions of vegetation succession under various managed disturbance regimes. Watts and Kobziar argue that, while both societal and ecological impacts of smoldering fires in wetlands are often viewed negatively (smoke hazards, carbon release, direct vegetation mortality), such fires may in fact increase the water storage capacity of smaller wetlands. This effect is valuable for wildlife that require surface water access during dry seasons, and with projected drier conditions to accompany climate change, such fire maintained refugia will likely increase in ecological significance. Finally, Jones *et al.* report on a method of using Landsat imagery to both document burn scars on the landscape and to determine post burn recovery. Their demonstration of how satellite imagery can thus be employed helps standardize the documentation of fire occurrence patterns in wetlands, which until now has included highly variable methods across different agencies and resource management authorities.

Our desire in creating this special issue is to open a forum among scientists working in the realm of fire and wetlands. We see this effort as a catalyst for researchers to identify research needs and direct studies to help understand the complex interactions of ecosystem development and function in systems where fire and water intersect. Regarding nutrients and fire effects on biogeochemical cycling, residue type (ash versus char), and level of fuel combustion appears to be a key factor governing release or deposition of both phosphorus and nitrogen (Osborne *et al*. 2009, Qian *et al*. 2009, Hogue and Inglett 2012). Thus, our ability to predict short- and long-term effects of fire on nutrient cycling and availability, microbial activities, and greenhouse gas production directly relates to our understanding of nutrient dynamics and transformations related to

fire intensity and severity. Likewise, understanding the role that fire plays in maintaining or modifying vegetation communities and habitats over space and time has far reaching implications for resource, landscape, and wildlife management.

It is also our intent that this special issue bring managers and researchers together to foster collaborative studies addressing critical unknowns. Land and ecosystem managers have appreciated the role of fire in maintaining and shaping wetland ecosystems for some time (Taylor 1981). Open discussions following the special session at the INTECOL conference allowed managers to provide perspectives on fire research and the value of research to the management community. A few important conclusions emerged from these discussions. First and foremost, the gap between research and application often stems from a lack of collaboration between researchers and practitioners. In many cases, managers have accumulated valuable and relevant field observations derived from extensive experience that can guide research as well as informing research-based recommendations. Too often, however, managers are not included in the research process or development of recommendations, and thus key needs are not adequately addressed.

The discussions surrounding the special symposium and this special issue were productive in identifying areas of scientific uncertainty and gaps in understanding that have direct management utility. Bearing in mind the need to include the management perspective in all stages of the research process, we determined there to be a significant need for continued research addressing the role of fire in wetlands with respect to modulating water quality and carbon cycling, maintaining native vegetation, modifying landscape features, and providing refugia for wildlife. A collaborative effort in which management needs and wisdom are incorporated in the development of research directives would best fill these knowledge gaps and ensure that research results are relevant to ecological wetlands management.

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