Forest Ecology and Management 304 (2013) 275–285

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Review

Amphibian response to downed wood retention in managed forests: A prospectus for future biomass harvest in North America

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ARTICLE INFO

Article history:
Received 20 February 2013
Received in revised form 16 April 2013
Accepted 17 April 2013
Available online 2 June 2013

Keywords:
Biofuel
Coarse woody debris
Frog
Salamander
Silviculture
Timber harvest

ABSTRACT

Harvest of forest biomass, specifically downed woody material (DWM), will increase to meet rising demand for alternative energy sources. Biomass harvest may reduce habitat quality, abundance, and regional diversity of forest-dependent species such as amphibians. We synthesize available literature conducted in landscapes managed for timber production to (1) assess the current state of knowledge regarding DWM management and amphibian population dynamics and (2) identify pertinent research gaps for future biomass studies. In general, the 25 studies we reviewed reported that amphibian counts were positively correlated with DWM levels. Although studies involving terrestrial salamanders often stressed the importance of retaining DWM in harvested systems, empirical support for this conclusion is uncertain due to study- and species-specific variation in responses. Lack of a DWM effect was often attributed to downed wood that was not well decayed or was too small for amphibian use. We identified several critical research needs, including: (1) understanding temporal dynamics of DWM (e.g., recruitment and decay rates) in regenerating forests and its influence on amphibian populations, (2) determining how amphibian use of harvest units relates to configuration and characteristics of DWM, (3) understanding how DWM management influences amphibian demographic rates, and (4) development of sampling and analytical techniques that support separation of sampling error and ecological effects. We suggest that future studies estimate effects of biomass harvest and identify, test, and refine operational harvest strategies that minimize impacts to amphibian populations. We emphasize research should be conducted at scales relevant to management; specifically, stand and landscape scales.

Contents

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http://dx.doi.org/10.1016/j.foreco.2013.04.023

1. Introduction

Global demand for natural resources is increasing amidst growing concerns over resource shortages, climate change, and threats to biodiversity. These factors have increased societal demand for renewable energy sources such as solar, wind, and biofuels (Turner, 1999; Armaroli and Balzani, 2007; Demirbas, 2007). In 2009, biofuels, or fuels derived from biomass conversion, accounted for ≈10% of global total primary energy use (International Energy Agency, 2010) and global production is increasing (Parikka, 2004; Ragauskas et al., 2006). For example, the Biofuels Program proposed by the United States Department of Energy has set a goal to replace 30% of petroleum transportation fuel with biofuels by 2030 (Biomass Program, 2012) and the US Energy Independence and Security Act of 2007 requires an annual production of 36 billion gallons by 2022 (EISA, 2007). Many countries have intensified their use of forest biomass, and other cellulosic feedstock, for generating heat and electricity (Hillring, 2006; Demirbas, 2007; Verkeri et al., 2011). Forest biomass is expected to play a significant role in production of second-generation liquid biofuel (Khoo et al., 2008; Tan et al., 2008).

Although proponents emphasize apparent reduction in greenhouse gas emissions and energy independence from increased biofuels use (but see Schulze et al., 2012), relatively little is known about how harvest of woody biomass will impact biological diversity, especially forest-dwelling wildlife (Cook et al., 1991; Fletcher et al., 2011; Stoms et al., 2012). Woody biomass harvest includes the extraction of downed woody material (DWM), such as treetops, limbs, slash and felled small trees, during traditional silvicultural harvest of live trees (Rudolphi and Gustafsson, 2005). Although biomass harvest has not been studied extensively, numerous studies have emphasized that retention of residual woody structure on the forest floor may reduce negative impacts of timber harvesting on forest biota and ecosystem function (Payer and Harrison, 2003; Ucitel et al., 2003; McKenny et al., 2006; Riffell et al., 2011). Woody biomass harvest has the potential to exacerbate negative effects of timber harvesting on forest biota and ecosystem function because it involves additional removal of woody organic matter (Rudolphi and Gustafsson, 2005; Bunnell and Houde, 2010). Conceptual and empirical models for understanding the role of DWM in maintenance of biological diversity and ecosystem function in managed forests are needed to predict direction and quantify magnitude of ecological responses to biomass harvesting.

Amphibians are critical components of forest ecosystems due to their numerical abundance and roles as apex predators in detrital food webs (Burton and Likens, 1975; Davic and Welsh, 2004). Reductions to amphibian populations can have cascading effects that alter community composition and ecosystem function (e.g., Wyman, 1998; Beard et al., 2002; Whiles et al., 2006). Given their reliance on forest floor refugia, amphibian populations are particularly at risk from increased biomass harvest. Generally, amphibians respond negatively to timber harvesting (e.g., Petranka et al., 1993; deMaynadier and Hunter, 1995; Semlitsch et al., 2009) and wood retention has been proposed as a forest management technique for ameliorating negative effects (e.g., McKenny et al., 2006; Rundio and Olson, 2007; Owens et al., 2008). As a result, biomass harvest may conflict directly with what are generally perceived to be beneficial management practices for these taxa. Given that over 30% of amphibian species are at risk of extinction (Stuart et al., 2004; Wake and Vredenburg, 2008), and habitat degradation and fragmentation are often identified as primary causes of amphibian declines (Cushman, 2006; Hof et al., 2011), detailed evaluations of amphibian responses to biomass harvest are warranted.

Biomass harvest guidelines are being integrated into state, federal, and private management organizations (e.g., Washington State Department of Natural Resources, 2007; Pinchot Institute, 2010; Bennett et al., 2010; Michigan Department of Natural Resources, 2010; Forest Guild, 2012). However, science-based recommendations for evaluating impacts of biomass harvest on amphibians and other species are often lacking from guidelines. Furthermore, inferences regarding amphibian response to downed wood are often site-specific and spatial extent of individual research projects is often limited. Synthesizing available information across studies is necessary to evaluate potential ramifications of biomass harvest on amphibians across intensively-utilized landscapes. Identification of research gaps and information needs is also critical if ecologists are to take a preemptive approach to studying biomass harvest on amphibians, and thus inform future management decisions.

Here, we synthesize current state of knowledge regarding relationships between downed wood management and amphibian population dynamics. We emphasize information gaps and propose future research ideas to address the current disparity between management decisions and available science. To improve understanding of relationships between amphibians and downed wood retention, we review study designs and analytical techniques of past research and suggest methods to strengthen and expand inferences made from future studies.

2. Materials and methods

We reviewed the peer-refereed literature on amphibian responses to downed wood in managed forests throughout the US and Canada. Our review included literature from deciduous and coniferous forests, where forest management was conducted in or adjacent to wetlands, riparian zones, or upland habitat. All of the reviewed studies were conducted at the forest stand or within-stand scale: we did not identify landscape-scale amphibian research with a downed wood focus. Although we include general aspects of amphibian-forestry research, our review was focused on studies that included a specific DWM component. We considered studies with the primary objective to describe effects of silvicultural prescriptions to be ancillary unless they included a DWM component in some portion of their analysis. We did not include amphibian studies that discussed importance of DWM in mitigating timber harvest effects without presenting data or results to support this claim. We conducted the literature search using the Web of Science[SM] and a list of specific keywords (Appendix 1).