379 FOREST ECOLOGY AND MANAGEMENT SCIENCE TO SUSTAIN THE WORLD'S FORESTS

Ineffectiveness of local zoning to reduce regional loss and fragmentation of wintering habitat for white-tailed deer

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ABSTRACT

Land-use zoning and regulations are frequently used to protect habitat for species threatened by habitat loss and fragmentation. Habitat protection, however, is rarely followed by habitat monitoring; consequently, knowledge about the efficacy of zoning as a species conservation tool is limited. We used a time series of Landsat satellite imagery (1975–2007) to quantify habitat changes in and adjacent to 187 areas zoned on private, commercial forestlands to protect habitat for wintering white-tailed deer (*Odocoileus virginianus*) in Maine. Near the northern edge of their geographic range where snow can restrict mobility and access to forage, white-tailed deer depend on mature conifer forests as wintering habitat. Our primary objective was to evaluate effectiveness of land-use zoning to conserve and prevent fragmentation of mature conifer forest. Between 1975 and 2007, the incidence rate of timber harvesting in zoned areas was high (97%). Cumulative area harvested (25%) and the associated reduction of mature conifer forest (13%) that resulted from stand-replacing harvests were considerably lower in zoned areas, indicating that regulations were successful at limiting timber harvests within zones. Reduction of mature conifer forest within unzoned 2-km buffers surrounding protected areas was considerably higher (45%). Remaining patches of mature conifer forest became increasingly fragmented, with a greater than 3-fold increase in number of patches and greater than 80% reduction in mean patch area. Regenerating forest increased from 5% to 36% in the landscapes surrounding zones, and although it can offer important browse, travel across young forest is costly for deer during periods of deep snow. Circa 2007, approximately 55% of the mature conifer forest present across our study area in 1975 remained, and our results suggest that less than 50% of the regenerating areas harvested in mature conifer forest will return to conifer dominance. Forest type conversion will, thus, extend effects of habitat fragmentation into the future. Areas protected for wintering deer collectively represent only 2% of the forested land base in our study area, and we conclude that habitat protection focused solely on those narrowly-defined zones has been ineffective at achieving regional conservation of winter habitat for deer. This study demonstrates how remote sensing can be used to overcome the difficulty of monitoring protected forest areas, and exemplifies the need for monitoring to understand the long-term benefits of zoning as a means of wildlife habitat conservation.

1. Introduction

Protection of habitat through land use zoning is widely considered to be an effective tool for maintaining populations of species threatened by habitat loss and fragmentation. Increasingly, zoning to support multiple-use activities is being incorporated into the design of nature reserves to manage conflicts between competing land uses (Hull et al., 2011). In the U.S., designation of *critical habitat* forms the foundation for establishing protected areas for species listed as Endangered or Threatened, in which some federal or federally-funded activities that could reduce extent or degrade quality of habitat identified as critical are limited. At the state-level, habitat conservation through land use regulation is also a widely applied. Whereas protections at the federal level are most commonly directed at the habitats of endangered and threatened species (Hagen and Hodges, 2006), state regulations often address habitats of game species and other species of regional significance (Amestoy and Di Stefano, 1990). Despite widespread application, there is limited evidence that species respond demographically to zoning (Hagen and Hodges, 2006). Further, an important question remains unanswered: can zoning be an effective wildlife conservation strategy if land use in the surrounding landscape is unregulated (Hansen and Rotella, 2002)?

White-tailed deer (*Odocoileus virginianus*) are a culturally, re-creationally, and economically important species of wildlife in the U.S. White-tailed deer are the most popular hunted species in North America, and also highly valued for non-consumptive viewing (McShea et al., 2007). In the northern U.S. and in southern Canada, populations of white-tailed deer are often limited by population-level effects of winter severity, interacting with the quality, distribution, and extent of wintering habitat. Correspondingly, wintering habitat requirements of white-tailed deer and characteristics of "deeryards" or areas where deer congregate during harsh winter conditions have been widely researched. White-tailed deer near the northern edge of their geographic range require wintering habitat when snow conditions restrict mobility (Parker et al., 1984) and access to preferred forage (Dumont et al., 1998, 2005). Mature conifer trees, which are especially effective at intercepting falling snow, are considered to provide critical shelter from wind and snow (Verme, 1973; Moen, 1976; Potvin and Huot, 1983; Lishawa et al., 2007). Forest stands comprised of mature conifer trees have reduced snow depths, reduced wind speeds, reduced radiant heat loss, and higher temperatures compared to deciduous or mixedwood stands (Lishawa et al., 2007). Within mature conifer stands deer are able to establish trail systems that increase mobility and access to forage (Huot, 1974).

In the state of Maine, U.S.A., deer wintering areas located throughout the northern, western, and eastern regions of the state are considered essential to the maintenance of public-derived population goals for white-tailed deer. The Maine Department of Inland Fisheries and Wildlife (MDIFW) identifies and maps deer wintering areas for protection under the existing process for zoning Wildlife Protection Subdistricts (P-FWs) (Dept. of Conservation, Maine Land Use Regulation Commission 1997, statute TITLE 12, M.R.S.A., Chapter 206-A Land Use Regulation, Chapter 10 Land Use Districts and Standards) across the 4.2 million ha under state zoning authority (Fig. 1). These areas also meet the legal definition of a *Significant Wildlife Habitat* under Maine's Natural Resources Protection Act.

The majority of the land under state zoning authority is privately-owned and commercially-managed forestland. If a planned land use activity is identified as having the potential to adversely impact a designated area of Significant Wildlife Habitat the landowner must obtain a permit from Maine's Land Use Planning Commission, which may require modifications of the planned activity to reduce impact. Alternatively, in the case of logging within a P-FW established for deer habitat protection, no permit is required if a landowner has a timber management plan approved by a MDIFW biologist that ensures the area of winter cover is not reduced. The species of conifer trees that often occur in P-FWs can have considerable economic value and zoning restrictions may result in reduced harvest volumes, lost future gains in annual allowable cut, increased road costs, or increased operating costs for a landowner (Bothwell, 2017).

Application of existing regulations has resulted in the past zoning of approximately 70,000 ha of P-FWs, representing 1–2% of the land base under state zoning jurisdiction. Despite these efforts at protection, loss of mature conifer forest has been identified as the major limiting factor compromising efforts to increase the numbers of deer in northern, western, and eastern Maine (Lavigne, 1999). In 2007, MDIFW qualitatively estimated that wintering habitat for deer in those areas had declined from approximately 10% of the total land area to less than 5% since the early 1970s (MDIFW, 2007). Coupled with the potentially significant costs that zoning represents to landowners, these outcomes have stimulated ongoing policy debates regarding the need to regulate or zone additional deer wintering areas. At the time that this study was initiated, MDIFW had established an objective to increase the zoning for protection of mature conifer forest for wintering deer to 8–10% of the land base (by 2030 or sooner) to ensure sufficient habitat to support a post-hunt population of 3.9–5.9 deer/km^2 (MDIFW, 2007). To achieve this, greater than 400,000 ha of forestland was discussed for additional zoning as P-FWs; some landowners expressed concerns that such
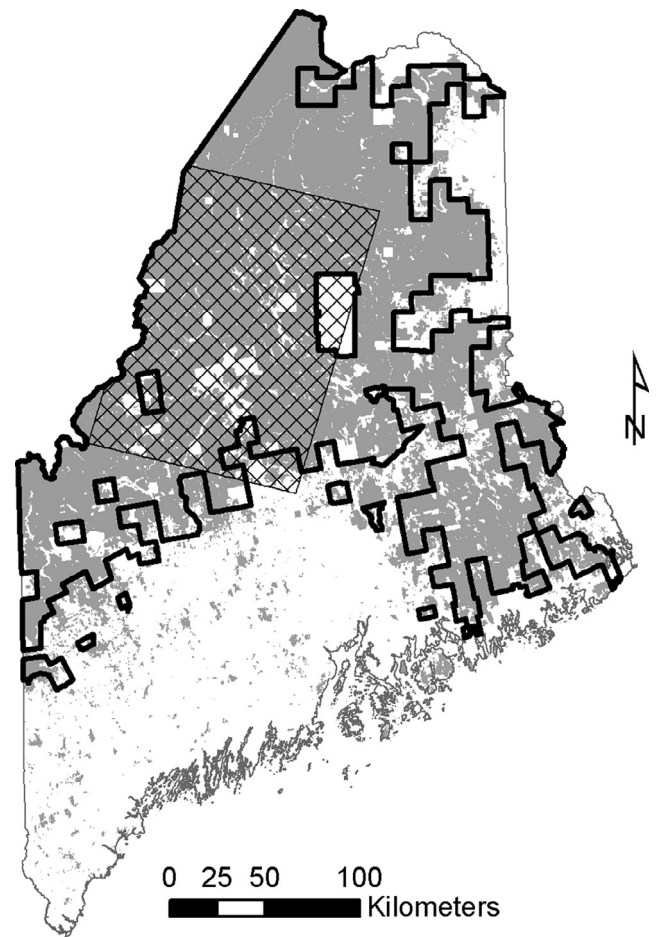

Fig. 1. The study area (hatched area) encompassed ~1.46 million hectares of commercial forestland (shown in gray) in Maine, U.S.A. Zoning within this area is primarily under the jurisdiction of the state's Land Use Planning Commission (bold outline).

expansions of regulated deer wintering areas could reduce market value of timberland, reduce annual stumpage income, and reduce the number of forest-related jobs statewide. A critical missing component in the process of debating the merits of increased zoning for white-tailed deer in Maine was a quantitative evaluation of the effectiveness of zoning under the existing laws and land-use regulations during the previous decades.

Evaluating the effectiveness of federal or state land use regulations aimed at protecting wildlife habitat is a daunting task and monitoring of habitats following protective laws and regulations is infrequently accomplished, even for U.S. federally-listed species (Campbell et al., 2002). Consecutive satellite images of an area provide unique opportunities to evaluate habitat change across large areas (Simons-Legaard et al., 2016), including the ability to compare lands protected by laws and regulations with the surrounding landscapes lacking similar protections. Such assessments can be particularly insightful when species-habitat relationships are well understood and can be tightly linked to forest conditions that can be monitored with remotely sensed imagery (Simons-Legaard et al., 2016). The goals of our project were to demonstrate how knowledge of wildlife-habitat relationships may be coupled with remote sensing to monitor the effectiveness of laws and regulations to conserve wildlife habitat on privately-owned and commercially-managed lands and, more specifically, to evaluate the effectiveness of Maine's land use regulations to conserve mature conifer forest as habitat for deer.

We conducted an analysis of habitat loss and fragmentation within P-FWs, as well as across the landscapes surrounding the zoned areas.