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# Decline of forest structural elements across forest–urban interfaces is stronger with high rather than low residential density

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## Abstract

Residential development creates a variety of wildland–urban interfaces, which in turn, can affect biodiversity to different extents. Yet, the paucity of biodiversity research at wildland–urban interfaces limits our ability to guide management and conservation planning. We assessed the effect of residential density on vegetation structure (measured along 50 m transects) across urban–forest interfaces (at 0, 100 and 300 m from the urban boundary into urban and forest cover). We compared five functional forms of the effect of distance to a boundary (no-effect, linear, quadratic, piecewise linear, and categorical distance), which can vary with residential density (high and low) and identified the best models describing the proportional cover of five vegetation variables across urban–forest interfaces. We found the proportional cover of most vegetation structures had a high magnitude of change across forest–urban interfaces of high residential density (towns); whereas smoother transitions were found across forest–urban interfaces of low residential density (rural residential). Town interiors exhibited the lowest estimated proportional cover of structural elements characteristic of forests (95% CI: litter = 0–0.05, understory = 0.01–0.03, projective foliage = 0.04–0.18). In contrast, rural residential interiors retained structural elements typical of forests (95% CI: litter = 0.89–0.99, understory = 0.11–0.27, projective foliage = 0.24–0.6). The proportion of understory in forest decreased with the proximity to an urban boundary, but the rate of decline was higher closer to towns than to rural residential areas. Because fauna heavily relies on vegetation structure, the loss of forest structural elements in towns and adjacent forests highlights the urgent need to plan for biodiversity conservation in these areas. Due to rapid urbanization of forest ecosystems worldwide, we discuss advances in land planning and fire risk management that may contribute to the conservation of vegetation structures at wildland–urban interfaces.

## Zusammenfassung

Der Ausbau von Siedlungen bringt eine Vielzahl von Berührungsstellen zwischen naturnahen und urbanen Habitaten hervor, wodurch wiederum die Biodiversität in unterschiedlichem Ausmaß beeinflusst werden kann. Indessen begrenzt die geringe Zahl von Untersuchungen an den Schnittstellen zwischen Stadt- und Naturräumen unsere Fähigkeit, eine Richtschnur für

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Management- und Naturschutzplanungen bereitzustellen. Wir bestimmten den Einfluss der Besiedlungsdichte auf die Vegetationsstruktur in 50-m-Transekten, die auf der Grenze zwischen Siedlungs- und Waldbereichen und beiderseits der Grenze jeweils 100 und 300 m von ihr entfernt lagen. Wir verglichen fünf funktionale Formen des Effekts der Entfernung zur Grenze (kein Effekt, lineare, quadratische, abschnittsweise lineare und klassenweise Entfernung), die mit der Bebauungsdichte (hoch und gering) variieren können, und wir identifizierten die besten Modelle, die die proportionale Bedeckung für fünf Vegetationsvariablen an der Grenze zwischen Siedlungs- und Waldbereichen beschrieben. Wir fanden, dass sich die proportionale Bedeckung der meisten Vegetationsstrukturen an den Grenzen zwischen Siedlungs- und Waldbereichen bei dichter (städtischer) Bebauung erheblich änderte, während die Übergänge bei geringer (ländlicher) Bebauungsdichte weniger abrupt waren. Im Stadtinneren war die berechnete proportionale Bedeckung für waldtypische Strukturelemente am geringsten (95%-Konfidenzintervalle für Streu = 0–0.05, Unterwuchs = 0.01–0.03, Kronenprojektion = 0.04–0.18). Dagegen erhielten sich waldtypische Strukturelemente im Innern ländlicher Siedlungen (95%-Konfidenzintervalle für Streu = 0.89–0.99, Unterwuchs = 0.11–0.27, Kronenprojektion = 0.24–0.60). Der Anteil von Unterwuchs im Wald verringerte sich mit der Nähe zum Stadtrand, aber die Abnahmerate war in der Nähe von Städten höher als in der Nähe von ländlichen Siedlungen. Da die Fauna entscheidend von der Vegetationsstruktur abhängt, betont der Verlust von waldtypischen Strukturelementen in Städten und angrenzenden Wäldern die dringende Notwendigkeit, den Schutz der Biodiversität in solchen Gebieten zu planen. Wegen der schnellen Urbanisierung von Waldökosystem weltweit, diskutieren wir Fortschritte bei Landplanung und Feuerrisikomanagement, die dazu beitragen können, Vegetationsstrukturen an der Grenze von Natur- und Siedlungsräumen zu schützen.


***Keywords:*** Boundary; Edge contrast; Rural development; Towns; Urbanization; Urban fringe

## Introduction

Mosaics of land cover types create multiple kinds of boundaries (Forman 1995). Boundaries separate ecosystems in a landscape and can be important drivers of ecological change (Forman 1995; Porensky & Young 2013). Despite there being a vast literature on terrestrial boundaries (reviewed by Ries, Fletcher, Battin, & Sisk 2004;Harper, Macdonald, Burton, Chen, Brosofske et al. 2005; Porensky & Young 2013), biodiversity responses on both sides of an urban boundary remain under-explored (Bar-Massada, Radeloff, & Stewart 2014). Given the rapid and accelerating expansion of urban settlements (McDonnell, Hahs, & Breuste 2009; Stein, Carr, McRoberts, & Mahal 2012), the lack of attention to biodiversity in wildland–urban interfaces has resulted in a major knowledge gap.

A key factor influencing the distribution of biotic elements is the difference in composition or structure between juxtaposed environments on both sides of a boundary (i.e. edge contrast; Ries et al., 2004; Harper et al., 2005). In landscapes under urban development, the variety of urban growth forms can create different contrast edges (Hodgson, French, & Major 2007; Villaseñor, Blanchard, Driscoll, Gibbons, & Lindenmayer 2015). For instance, wildland–urban interfaces of high (or medium) residential density may be considered high contrast edges because forest and urban areas differ markedly in composition and structure (e.g. suburbs, towns; Fig. 1A). In contrast, wildland–urban interfaces of low residential density that retain natural vegetation may represent low contrast edges (e.g. exurban development, rural residential areas; Fig. 1B).

Previous research suggests that the strong negative effects on wildlife of wildland–urban interfaces of high residential density may be due to a reduced availability of key vegetation structures for fauna (Hodgson et al., 2007; Villaseñor, Driscoll, Escobar, Gibbons, & Lindenmayer 2014). However, what appear to be minor modifications to land cover with low residential density, can, in fact, result in major modifications to the local vegetation (Reed, Kretser, Glennon, Pejchar, & Merenlender 2012). Thus, it is important to know the effect of residential density on vegetation structures across urban–forest interfaces, to help guide targeted management and conservation actions in the urban fringe.

We conducted an empirical study to evaluate the effect of residential density on vegetation structure (i.e. proportional cover of vegetation layers) from urban areas into wildlands. We focused on forest–urban interfaces because the rapid increase of forest–urban interfaces is demanding an improved understanding of vegetation structure to plan for biodiversity conservation while managing fire risk (Stein et al., 2012; Bar-Massada et al., 2014). Furthermore, we studied small towns and rural residential areas because most urban studies have focused on cities or major towns (McDonnell et al., 2009), yet there is limited research on the effect of small urban settlements on biodiversity. Therefore, our study addresses these current knowledge gaps by providing empirical evidence about the changes in structural vegetation across forest–urban interfaces of high and low residential density (towns and rural residential areas, respectively) and discusses their implications for biodiversity conservation. In addition, our study contributes to the literature on terrestrial boundaries by evaluating the effect of a factor (edge contrast, as indicated by residential density) in functions describing responses across adjacent ecosystems.