



Work more and play less? Time use impacts of changing ecosystem services: The case of the invasive emerald ash borer



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ABSTRACT

Invasive alien species may have indirect impacts on human behavior through disruption of ecosystem services. Individuals in infested areas may optimally reallocate how they spend their time in response to degradations in environmental quality, for example, by altering their outdoor interactions with nature or levels of community engagement. Limited qualitative evidence is suggestive that indirect impacts of invasive species on behavior and time use may be substantial, though causally-consistent empirical evidence on the sign and magnitude of such impacts is lacking. To address this gap, this study exploits a natural experiment provided by exogenous variation in ash tree (*Fraxinus* spp.) coverage produced by the invasive emerald ash borer (*Agrilus planipennis*) to investigate changes in time use patterns across infested US counties over 2003–2013. Focusing on the labor–leisure decision, results indicate a negative and persistent relationship between emerald ash borer detection and daily outdoor leisure time as well as a positive and persistent relationship between detection and daily time spent on labor market activities. Results highlight a previously unexplored dimension of impacts created by invasive species induced ecological shocks.

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1. Introduction

Invasive alien species may have indirect impacts on human activities and well-being through disruptions to ecosystem services. According to the World Health Organization (2015), ecological impacts of invasive species on biodiversity represent an existential ongoing threat to how people live and interact in their communities. While investigations of direct impacts of invasive species on human well-being have been made (e.g., Mazza et al., 2014; Vilà et al., 2010; Crowl et al., 2008), including cases of economic benefits (e.g., Pienkowski et al., 2015), there is a growing acknowledgement that invasive species may have nuanced and complex indirect anthropogenic impacts through ecosystem change, such as impacts on behavior and time use patterns (Pyšek and Richardson, 2010; Pejchar and Mooney, 2009). The European Environment Agency (2012) cautions that ecological disruption caused by alien species will likely precipitate “complex, unpredictable cascades of effects” on human behavior, due to factors such as global climate change and increasing international movements of people and goods. However, there is a gap in the literature on quantitative measures indirectly linking invasive species to human behavior vis-à-vis ecosystem change. This absence of empirical assessment on indirect effects hinders

our ability to holistically evaluate and predict when and where invasive species might produce “cascades of effects” and hence be most deleterious.

The objective of this analysis is to provide the first estimates of indirect human behavior changes associated with detection of an invasive species by using a natural experiment that caused a sharp degradation of ecosystem services, and hence a sharp decline in environmental quality, within a relatively short period of time across the Midwest and Northeast US. Tens of millions of ash trees (*Fraxinus* spp.) have died in the US over the past decade due to the introduction of invasive emerald ash borer (*Agrilus planipennis*), EAB hereafter, sharply reducing the size and diversity of forest canopies (Herms and McCullough, 2014). This analysis explores the effect of EAB, and thus reductions in environmental quality, on allocation of time among individuals living in EAB infested US counties. Specifically, we investigate the so-called “labor–leisure decision” of how an individual allocates time between labor market and leisure activities. Labor and leisure activities are selected because they represent the second and third largest use of daily time, respectively, among US adults, behind sleeping (Tudor-Locke et al., 2011), and are important determinants of overall human well-being (Krueger, 2009).

Disruptions to forest ecosystems caused by alien species may affect labor and leisure time use either positively or negatively depending on underlying relationships between people and trees. Leisure time may be higher and labor time lower in areas abundant with trees

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because of increased recreational opportunities. People living proximal to forests and greenspace often spend more time outdoors and engage in more exercise than their peers (Coombes et al., 2010), perhaps at the expense of time spent working. Alternatively, ecosystems sustained by forests promote neighborhood cohesion and meaningful social interactions (Maas et al., 2009; Kuo, 2003), which might result in increased economic opportunities and partnerships, increasing time devoted to labor. It is unclear from a qualitative perspective which, if any, of these factors might dominate. This has precipitated calls for additional quantitative research on indirect anthropogenic impacts of invasive species (Katsanevakis et al., 2014; McLaughlan et al., 2014) using stronger identification strategies to address issues of ecological confounding (Frumkin, 2013). Such research can inform ongoing debates on management prioritization guided by a more complete understanding of ecological and economic “impact” of invasion, and provide information on determinants of time allocation in response to ecological shocks.

This analysis exploits a natural experiment that created large and exogenous reductions in environmental quality through the sudden loss of ash trees due to invasive EAB. Natural experiments are useful when randomized controlled trials are unavailable, as they provide an exogenous source of variation in exposure, independent of outcome, strengthening identification (Meyer, 1995). Natural experiments have previously been used to study EAB and health risks (Donovan et al., 2015; Donovan et al., 2013), though this is the first application of this method to EAB and time use allocation. A fixed effects cross-county comparison design is used to explore individual labor and leisure time allocations before and after EAB detection, for a nationally representative, repeated cross-section sample of US adults in the American Time Use Survey.

2. Background

2.1. Invasive Species and Their Impacts

There are many ecological economic dimensions of invasive species, including market and nonmarket benefits and costs (Pienkowski et al., 2015; McDermott et al., 2013; Pimentel, 2011), the public goods nature of biological exclusion and control (Ricciardi et al., 2011; Perrings et al., 2002), invasives as a threat to public health and well-being (World Health Organization, 2015; Jones and McDermott, 2015; Donovan et al., 2013), global economic drivers of biological invasion (Dalmazzone and Giaccaria, 2014), and models of ecosystem changes (Gallien et al., 2010; Cook et al., 2007). A focus has been on the direct economic costs associated with biological invasion (e.g., Aukema et al., 2011; Kovacs et al., 2010) and the use of invasive species management to mitigate direct impacts (e.g., Vannatta et al., 2012; Settle and Shogren, 2002). Less attention has been given to indirect impacts, such as human behavioral patterns and interference with day-to-day activities, where impacts may be particularly significant (Cardinale et al., 2012; Perrings et al., 2002).

Presence of an invasive pest may have direct and indirect effects on behavior. We might expect to observe changes related to protection of native habitats and management of invasive pests through control and eradication, directly caused by detection. For example, farmers or homeowners may spend more time outdoors removing invasive weeds or spraying them with herbicides. Management of a biological invader may also create employment opportunities or shift time use patterns for certain types of workers. Indirect behavioral effects of alien species induced by changes in environmental quality are also possible. For example, reductions in biodiversity or loss of environmental aesthetics due to an invasive pest may attenuate time spent outdoors and time engaged in outdoor recreation activities, for example, walking, hiking, sports, or camping (Nilsson et al., 2011). Tuomainen and Candolin (2011) report that not only are behavioral changes in response to ecosystem degradation common both today and throughout history, but also are often rapid and immediate, as individuals search for more favorable day-to-day living arrangements and social outcomes. Therefore, a

case can be made that by impacting environmental quality, invasive species may have immediate and meaningful effects on behavior and time use patterns, especially in cases where ecosystem change is significant.

Additionally, behavioral changes induced by invasive species may persist through time. Disruptions to ecosystems due to invasive pests are often long-term and can even be permanent in some cases (Pejchar and Mooney, 2009). For example, in the case of EAB, degradation of the forest ecosystem may persist for many years until non-ash replacements are introduced and grow to maturity (Herms and McCullough, 2014). The duration of time between ash fall and when a replacement is planted (or the forest naturally repopulates) and grows to maturity can be several decades, depending on a variety of factors such as replacement species, weather, soil quality, management intensity, and financial budgets. It is therefore likely that time use impacts of an invasive pest could last for several years, if not decades.

2.2. Natural Experiments as a Source of Ecological Variation

Confounding factors make it difficult to establish independent impacts of environmental quality on time use allocations, and labor–leisure decisions in particular. Correlational studies analyzing cross-sectional data cannot demonstrate a causal relationship. Wealthier households (who often work more hours) can afford to live in places with better environmental quality (Hobden et al., 2004) and are also more likely to exercise than less well-off households (Popham and Mitchell, 2007). Wealth or income might be a strong determinant of both labor and leisure time use as well as a strong determinant of environmental quality in the area where a person lives. This makes it challenging to estimate the independent causal role of quality on time use. More sophisticated identification strategies are required to tease out such nuanced mechanisms.

Natural experiments are often used to provide more suggestive evidence of correlational relationship when randomized trials are unavailable. While natural experiments cannot fully demonstrate causality, they exploit degrees of randomness over which treatments are applied, which is an important missing component from correlational studies. The randomness exploited in such studies may strengthen the identification strategy and has the potential to greatly increase our understanding of important economic relationships (Angrist and Krueger, 2001).

In a recent natural experiment specific to invasive species, Donovan et al. (2013) exploited exogenous detections of EAB in US counties to investigate the relationship between human health and ecosystem services provided by forests. Since spread of EAB is quasi-random by flight and economic activity there is a certain degree of randomness present in treatment assignment; an important tenant of natural experiments. Donovan et al. (2013) found that EAB detection was associated with 21,193 excess cardiorespiratory deaths over 2002–2007, which was posited to be a consequence of changes to forest ecology. Similar and more recent work, again using EAB detection as a natural experiment, suggests that women are at greater risk of cardiorespiratory disease after detection of EAB in their county of residence, perhaps due in part to behavioral shifts in time allocation (Donovan et al., 2015). Whether or not, and to what degree, shifts in time allocation are occurring in response to EAB detection is an open question that if answered would provide evidence of a new dimension of invasive species impacts.

To address this gap, this study exploits a natural experiment created by quasi-random county-level detections of EAB from 2003 to 2013. We investigate two research questions: (i) does EAB affect the decision to participate in labor or outdoor leisure activities?; and (ii) what is the magnitude of the labor–leisure EAB effect and for how long does it persist? This analysis contributes to the literature on social impacts of invasive species by providing the first quantitative estimates of time use externalities associated with ecological disruption caused by an invasive pest, EAB.

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