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Responses of bats to clear fell harvesting in Sitka Spruce plantations, and implications for wind turbine installation

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ABSTRACT

Commercial coniferous plantations are often assumed to be poor habitats for bats. As a result, the impact of forest management practices on bats, such as clear felling, has received little attention, particularly in Europe. However, there is growing evidence from multiple regions that bats do make use of plantation landscapes, and as interest in siting onshore wind turbines in upland conifer plantations grows, there is an urgent need to examine whether felling prior to turbine installation is likely to put foraging bats at risk of collision. In the first study of its kind, we use a "before – after – control – impact" study to explore the short-term impacts of clear fell harvest on bat activity in commercial plantations. Thirty-one mature stands of Sitka Spruce were surveyed using acoustic detectors in three large, upland Sitka Spruce plantations in Britain. Eleven stands were felled between 2013 and 2015, and 26 of the original 31 stands were resurveyed in 2015. The change in total bat activity and species- or genus-specific bat activity was modelled before and after felling occurred at both felled and control stands using generalised linear models. There was no change in overall bat activity at felled sites compared to control sites, but activity of *Nyctalus* species was 23 times higher following felling. Total *Pipistrellus spp.* activity doubled at felled sites post-harvesting, although this was mainly driven by increased activity at a few felled sites. When *P. pygmaeus* and *P. pipistrellus* were considered separately, activity increased slightly but non-significantly. The size of the felled area influenced activity (for bats overall and *Pipistrellus spp.*), with 90% higher activity in smaller felled stands (less than 5 ha^{-1}) compared to larger felled stands (greater than 30 ha^{-1}). For *P. pipistrellus*, activity in felled areas decreased with the duration since harvesting; the greatest activity occurred in stands felled within two months compared to those harvested more than 16 months previously. Higher activity for some groups following felling may occur due to the creation of more edge habitat, which is preferred by both *Pipistrellus* species we recorded. An increase in activity following the small-scale felling ('key-holing') required for the installation of turbines could put foraging bats at risk from collisions with turbines. Further investigation of the influence of both size of clear fell patch, timing of felling and changes in invertebrate abundance due to felling are required to establish the potential risk of key-holing and turbine installation to foraging bats.

1. Introduction

Large scale clear felling is a widely used form of timber extraction in commercial forests which has been heavily criticised for its perceived impacts, particularly on forest dependent flora and fauna (Borkin and Parsons, 2014; Lindenmayer et al., 2006). However, there is little consistency in the literature about the impacts of clear felling on biodiversity, with responses being highly taxa specific. Felling may negatively affect organisms by isolating populations, decreasing resources, increasing predation or changing climatic conditions (Grindal and Brigham, 1998). For example, forest specialists may be negatively affected due to increased predation risk from the lack of cover (e.g. arboreal sciurids; Fisher 2005). However, felling may be beneficial for open and edge adapted species, particularly successional species, which respond positively to the changes in vegetation structure and composition caused by harvesting and preferentially use clear-cuts (e.g. some early successional birds; Loeb and O'Keefe, 2011; Oxbrough et al., 2010; Paquet et al., 2006). Eycott et al. (2006) found that plant species richness is 60% lower in stands with full canopy closure and increased in the first few years post-harvest as regeneration occurs. Regeneration may be positive for some invertebrate taxa (Lin et al.,

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2006), but less so for canopy specialists (Humphrey et al., 2003). Typically, generalist and open specialist species appear to benefit from clear felling, while forest specialist abundance and diversity decreases (Humphrey et al., 2003; Ohsawa and Shimokawa, 2011; Oxbrough et al., 2010). Therefore, while species richness may not necessarily change in response to felling pressure, community composition can be altered.

Many habitat selection studies have found that bats avoid commercial coniferous plantations (Boughey et al., 2011; Jones et al., 2003; Smith and Racey, 2008; Walsh et al., 1996), which is often attributed to low invertebrate density and increased structural complexity, amongst other factors (Haupt et al., 2006; Russo and Jones, 2003; Smith and Racey, 2008). However, often these studies are carried out in areas of extremely low conifer cover (e.g. conifer cover of less than 3%, Davidson-Watts and Jones, 2005; Davidson-Watts et al., 2006) and there is growing evidence that certain bat species are able to make use of intensively managed non-native plantations in landscapes dominated by plantations (Charbonnier et al., 2016; Cistrone et al., 2015; Kirkpatrick et al., 2017; Mortimer, 2006; Russo et al., 2010). While the impacts of logging forests have been investigated for a number of different bat species worldwide (e.g. New Zealand: Borkin and Parsons, 2010a, 2010b; USA: Grindal and Brigham, 1998; Australia: Law and Law, 2011), much of the previous work has concentrated primarily on old growth or native forests (Dodd et al., 2012; Grindal and Brigham, 1998; Loeb et al., 2006; Loeb and O'Keefe, 2011; Menzel et al., 2002; Patriquin and Barclay, 2003). The impact of forest management practices in non-native commercial plantations has received far less attention. Research that does exist has focused on the impacts management may have on forest specialist bats which rely on tree roosts for much of their life cycle (Borkin et al., 2011; Borkin and Parsons, 2014). For bat species which are adept at using anthropogenically-disturbed habitats and rely on building roosts rather than tree roosts, commercial coniferous plantations may be a landscape which they can exploit (Kirkpatrick et al., 2017).

Bats with home ranges dominated by plantation forests, are likely to come into contact with felling operations (Borkin and Parsons, 2011). Features such as standing dead wood, snags, tree damage such as double leaders, and peeling bark all form key roosting habitats for bats and other taxa (Altringham et al., 1996; Arnett, 2007; Russo et al., 2010). However, in some plantation systems, trees are removed before these features develop due to reaching economic maturity, safety concerns, damage, fire risk or to limit the spread of parasites (Russo et al., 2010). Depending on the plantation system, felling may therefore directly cause direct mortality by removal of a roost that is currently occupied by a bat colony or indirect mortality through impacting reproductive fitness and success as the number of roost trees within a colony home range is reduced (Borkin and Parsons, 2014). Therefore remnant patches of either native or old growth trees may constitute the only available appropriate natural structures for roosts (e.g. Burgar et al., 2015; Lindenmayer and Hobbs, 2004).

Clear felling causes an immediate and substantial change to stand structural complexity, which may benefit foraging success in edge and open adapted bats (Adams, 2012; Elmore et al., 2005; Kirkpatrick et al., 2017). In stands with substantial vegetative clutter, bat activity will be reduced due to constraints on both echolocation and manoeuvrability (Dodd et al., 2012; Morris et al., 2010; Patriquin and Barclay, 2003), and bat activity is likely to increase once clear felling has occurred. Felled stands may support a similar invertebrate abundance compared to mature forest (Dodd et al., 2012; Lacki et al., 2007; Ohsawa, 2005; Oxbrough et al., 2010), particularly in non-native plantations, where felled plantations can be bordered with mature stands, resulting in edge habitat which provides protection from wind and predators (Nicholls and Racey, 2006). Furthermore, invertebrates may accumulate passively along edge habitats due to wind (Law and Law, 2011; Verboom and Spoelstra, 1999). Even when invertebrate availability is lower in felled stands compared to mature stands, bat activity may be higher, suggesting that the structure of the habitat may be more important than prey abundance in determining the spatiotemporal foraging patterns of bats (Adams et al., 2009; Dodd et al., 2012).

Previously, we found evidence of *P. pipistrellus* and *P. pygmaeus* making widespread use of three large, predominantly Sitka Spruce (*Picea sitchensis*) plantations in Scotland and Northern England, with all other species in this geographic range also detected, albeit in low numbers (Kirkpatrick et al., 2017). There was also evidence that *Pipistrellus spp.* preferentially associated with felled areas (Kirkpatrick et al., 2017), suggesting that some species may increase their foraging activity as a result of harvesting operations. Therefore, providing roost structures are not removed or damaged in the process, felling may result in increased bat activity in commercial plantations.

Knowledge of how bats respond to felling practices is important in understand the potential implications of siting wind turbines in plantations, a practice which has greatly increased in recent years. There is overwhelming evidence to suggest that wind turbines cause both direct and indirect mortality through barotrauma, collision, and avoidance resulting in changes to habitat use (Voigt and Kingston, 2015), although the extent to which such effects can exert population level impacts is likely to vary greatly between regions. Therefore, a further consideration of this work was to investigate how bat activity changed in response to the size of the clear felled area and the time since felling, and relate this to forest management practices carried out to install wind turbines in commercial plantations.

To our knowledge, the impact of felling on foraging activity of bats in commercial plantations has not been experimentally tested (but see Grindal and Brigham (1998) for a similar study in native forest). In this study we used a before – after – control – impact (BACI) design to quantify the effect of felling on bat activity in the short term (between 1 and 16 months post-felling).

Specifically, we aimed to answer the following questions:

1. What is the short term influence of felling on bat activity and behaviour?
2. What influence does the size of the felled area have on bat activity?
3. How does the age of the clearfell (i.e. time since felling) influence bat activity?

We predict that in the short-term activity is likely to increase post felling with the creation of new edge habitats. Furthermore, we predict that it is likely that the greater increases in activity will occur in the smaller stands compared to the larger stands. Finally, bat activity could be expected to increase as time since felling increases due to the short term change in vegetative structure which may support more invertebrate prey. As we are looking at changes within two years of harvesting, substantial regeneration is unlikely to have occurred which would be likely to reduce bat activity (Law and Law, 2011).

2. Methods

The study was conducted in three large, intensively managed plantation forests in Central and Southern Scotland, and Northern England (Cowal and Trossachs: 56.188, −4.509; Galloway Forest: 55.117, −4.4728; Kielder Forest: 55.158, −2.442). All three forests were chosen because of their large size (between 30,000 and 114,000 ha), high productivity and predominance of *Picea*