**Suboptimal forest habitat buffering bird decline caused by hemlock woolly adelgid**

**Introduction**

Anthropogenic activities have accelerated the rates of biological invasions by many orders of magnitude (Vitousek et al. 1997, Lockwood et al. 2007). Humans have significantly changed geographic patterns of biological invasions, creating a range of opportunities to species overcome biogeographic barriers to colonize new areas outside of their original distribution. More than 450 nonnative species of insects and tree pathogens have invaded and established the United States. Non-native organisms cause serious economic and ecological problems, and the loss of native species and ecosystem (Andow 2005, Perrings et al. 2005). Although the majority of these introductions had minimal impacts, (Wu et al. 2017) identified a list of 83 species that cause severe damage in the forest – jeopardizing tree health and causing tree mortality. In eastern US, forest landscapes dominated by the eastern hemlock tree (*Tsuga canadensis*) are being intensely affected by the infestations of the invasive hemlock woolly adelgid (*Adelges tsugae*) (Ford et al. 2011, Wu et al. 2017). With the arrival of the hemlock woolly adelgid, hemlock mortality has almost tripled in areas with more than ten years of infestation, whereas areas with 35+ years of infestation have mortality rates 7 times higher compared with areas where the adelgid is absent (Wu et al. 2017). This raises great concern for the conservation of forests in easter US: the eastern hemlock is one of the most important species in the landscape and it is considered a foundation species (Ellison et al. 2005, 2010).

Substantial declines in bird populations in eastern North America have been documented since the early 80s, and they have strongly been associated to habitat alteration (Holmes and Sherry 2001, Rosenberg et al. 2019). One of the primary factors influencing habitat selection, and consequently bird abundance and distribution, is vegetation configuration and composition (Block and Brennan 1993, Lee and Rotenberry 2005). Changes in vegetation are mirrored by changes in the composition of avian communities: according to habitat suitability governed by environmental or geographical gradients, specific bird species might appear, disappear, decrease or increase in density (Block and Brennan 1993, Lee and Rotenberry 2005). Hemlock stands provide important habitat where birds can forage, nest, and roost. Several studies have shown that forest landscapes that include hemlocks have greater avian diversity (Gates and Giffen 1992), and that the mortality of hemlocks critically affect the local bird communities (Askins and Philbrick 1987, Yamasaki et al. 1999, Tingley et al. 2002, Becker et al. 2008, Allen et al. 2009, Brown and Weinkam 2014, Toenies et al. 2018) Ross et al. 2004. Although these studies provide invaluable insights about the effects of the woolly adelgid in local avian populations, the extent of the landscape scale effect of hemlock tree mortality in different bird species is still unclear if we consider their entire distribution ranges.

A core group of species has been described by several of these studies as hemlock dependent: Acadian Flycatcher *(Empidonax virescens*), American Redstart (*Setophaga ruticilla*), Black-and-white Warbler (*Mniotilta varia*), Blackburnian Warbler (*Setophaga fusca*), Black-throated Green Warbler *(Setophaga virens*), Blue-headed Vireo (*Vireo solitarius*), Canada Warbler (*Cardellina canadensis*), Eastern Wood-Pewee (*Contopus virens*), Hermit Thrush (*Catharus guttatus*), Hooded Warbler (*Setophaga citrina*), Ovenbird (*Seiurus aurocapilla*), and Winter Wren (*Troglodytes hiemalis*).

Benzinger, 1994