Predicting Occupancy in bats from landscape variables in the Sierra Nevada Ecosystem, California

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# Introduction

Bats are one of the most diverse group of mammals with around 1240 species (Tudge 2000; Schipper et al. 2008), second only in number of species to rodents. The distinctive characteristic of this group is their ability to fly. They live in every continent but Antarctica. Most of them are insectivores, but some of them are pollinators and some very specialized species are hematofagous or carnivorous (Kunz 2013). most are nocturnal, and rely on echolocation to detect their preys and navigate through space.

Chiropterans are the only mammals to achieve powered flight, bats have several adaptations for this (Norberg 1998). It is supposed that ancient bats started flying around 50 million years ago (Cooper, Cretekos, and Sears 2012), developing an enlarged hand with a thin membrane between the enlarged fingers, which is very different from the wings of birds. Little is known of the evolution of flight in bats, since the earliest fossils found of these groups were already winged (Gunnell and Simmons 2005; Jepsen 1966). However wings are not the only adaptation that bats and birds share, they both have higher metabolism and internal temperature than other flightless vertebrates of the same size, their bones are lighter, and have enlarged pectoral muscles that allow them to fly (Norberg 1998).

Echolocation is a biological process exclusive to bats, toothed whales, and a few species of birds, it was a termed coined in 1938 by Griffin, who was the first author to thoroughly study the phenomenon (Griffin and Galambos 1941). The mechanism of echolocation is that the animal producess a sound, an then it bounces against an object, the intensity of the returning sound, plus the time difference between the returning sound at reaching both ears gives information regarding the distance and angle of the detected object (Jones 2005). Bats use this mechanism to detect their preys (Griffin, Webster, and Michael 1960), avoid obstacles, and even to detect water sources. Most bat calls are beyond the human hearing range, and they range in frequency from 14,000 to well over 100,000 Hz. Most species of bats produce very disctint calls, that has been used to detect and differenciate bat species by recording and analysing such calls as in the image below (Fenton and Bell 1981).

Bats are very important economically in the world. Their most important benefit without a doubt is that they feed on invertebrates and thus they are one of the major natural pest controls for crops, since over two thirds of all bats are obligated insectivorous(Kunz et al. 2011). Due to their insect control, only in agriculture, it has been calculated that bats save farmers in the United States 72 dollars/acre (Boyles et al. 2011), which projects to an economic value of $22.9 billion dollars a year in the United States for the agricultural industry. At the same time there are bats that are pollinators of flowers, and there are other frugivorous bats that help spreading seeds (Kunz et al. 2011). Bat pollination occurs in about 528 species of angiosperms world-wide. Even though most of north american bats are insectivorous, in arid habitats two families of succulent plants, Agavaceae and Cactaceae, rely on bats to be pollinated. Several of those species are very importance economically in northern and central america and supply food, fiber, tools, soaps, and medicine to the community as well as being the base of the multimillion dollar industry of tequila (Forster, Fleming, and Valiente-Banuet 2003).

The White Nose Syndrome (WNS) is a fatal bat disease produced by the fungus *Pseudogymnoascus destructans*, the origin of its name is the white color left on the infected skin of the muzzle, ears, and wings of bats (D. S. Blehert et al. 2009). This disease usually causes aberrant behavior of bats during hibernation, including bats prematurely staging at hibernacula entrances, failure of bats to arouse normally in response to disturbance, and diurnal and mid-winter emergence (Langwig et al. 2012).

*P. destructans* is capable of living at relatively low temperatures. Thermal performance curves generated for each isolate indicated thermal optima for growth between 12.5 and 15.8°C (54.5 to 60.44 °F) and an upper critical temperature for growth between 19.0 and 19.8°C (66.2 to 67.6°F) (Verant et al. 2012), no growth at 24°C (75.2°F) or above (Gargas et al. 2009). This makes this fungus to grow optimally at the temperatures found in winter bat hibernacula. Bats are thought to have a lowered immune responses during hibernation torpor (Carey, Andrews, and Martin 2003), this may predispose hibernating bats to infection by *P. destructans* (Gargas et al. 2009). To this date WNS has been estimated to have killed over five million North American bats (Verant et al. 2012).

WNS is dispersing notoriously trough North America. The first evidence of WNS in bats was detected on February 2006 in New York, and it was documented by a photograph taken at Howes Cave, 52 km west of Albany (D. S. Blehert et al. 2009). Until 2009, the disease was present only in the northeastern United States (D. S. Blehert et al. 2009), but lately it has been found throughout the midwest and on 2016 in the first case was detected in the west coast in the State of Washington (USGS 2016).

Besides WNS, the biggest threat to bats in north america is wind turbines. Every autumn high mortality occur when migrating bats crash into this turbines (Cryan 2011). In a review of all multiple mortality events, defined as events where more than 10 bats died at a specific location on the same date, it was estimated that wind turbines have been the cause of more cumulative multiple mortality events than any other reason, followed closely by WNS (O’Shea et al. 2016). From 2003 to 2013 at least 5,626 bats of 27 species in 18 countries where registered to have died in wind turbines (L. Rodrigues et al. 2015), and this should be only a fraction of the likely mortality, with estimations of 888,000 bat deaths only in north america for the year 2012 (Smallwood 2013). It is also important to note that mortality in not equally distributed among bat species most deaths that happen in wind turbines correspond to migratory species that roost in trees (Arnett et al. 2008).

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