Bats say: let California Burn

Derek Corcoran

May 5, 2016

# Introduction

Recent studies have shown that there has been an increase in both fire frequency and severity in all the West Coast of the United States and in the Sierra Nevada Range in Particular (Miller et al. 2009; Westerling et al. 2006). The increase in the fire frequency is both due to human activity (Syphard et al. 2007) and global change (Lenihan et al. 2003).

It is highly unlikely that this increment is reverted and thus it is very important to understand the impact of high intensity fires in the forest ecosystem. It has been predicted that fires will increase in frequency and area in the whole western coast of the United Sates as predicted through year 2100 (Liu and Wimberly 2016). In particular in Northern Sierra Nevada it has been established that fire suppression has homogenized the environments with a higher representation of fire intolerant species (Beaty and Taylor 2008). There is increasing evidence of a higher frequency of wildfires and an increase of area burned annually in Sierra Nevada (Miller et al. 2009) Specifically at higher elevations (Keeley and Syphard 2015; Schwartz et al. 2015).

The Sierra Nevada Bioregion is dominated by mixed-conifer forest with some redfire forest and evergreen conifer areas (Steel, Safford, and Viers 2015). With a fuel-limited fire regime (Steel, Safford, and Viers 2015). It has a Mediterranean climate with dry and warm summers and cool wet winters. The highest precipitation in the state of California corresponds to our study site in the northern limit of the Sierra Nevada (Wagtendonk and Fites-Kaufman 2006). Changes in the ecosystems and communities along the Sierra Nevada mainly follow a west-east gradient of altitude and rainfall due to orographic rains coming from the pacific coast, rainfall increases with altitude and as it drops to the east we find the driest environments. The most common environment is the lower montane forest (Wagtendonk and Fites-Kaufman 2006). The dominant species of this community are the Jeffrey Pine (*Pinus jeffreyi*) and Ponderosa Pine (*Pinus ponderosa*).

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. So far the response of bats to the change in the fire regime has been limited. The only works that research the response of bats to fire divides the environments in high and low intensity fires (Buchalski et al. 2013), but the response of this taxonomic group to fire is probably more complex than that, since understory fires increases the availability of insects (Lacki et al. 2009), which would be positive for bats, but high intensity basal and canopy fires diminishes roosting sites.

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).

# References

Arnett, Edward B, W Brown, Wallace P Erickson, Jenny K Fiedler, Brenda L Hamilton, Travis H Henry, Aaftab Jain, et al. 2008. “Patterns of Bat Fatalities at Wind Energy Facilities in North America.” *The Journal of Wildlife Management* 72 (1). Wiley Online Library: 61–78.

Beaty, R Matthew, and Alan H Taylor. 2008. “Fire History and the Structure and Dynamics of a Mixed Conifer Forest Landscape in the Northern Sierra Nevada, Lake Tahoe Basin, California, USA.” *Forest Ecology and Management* 255 (3). Elsevier: 707–19.

Blehert, David S, Alan C Hicks, Melissa Behr, Carol U Meteyer, Brenda M Berlowski-Zier, Elizabeth L Buckles, Jeremy TH Coleman, et al. 2009. “Bat White-Nose Syndrome: An Emerging Fungal Pathogen?” *Science* 323 (5911). American Association for the Advancement of Science: 227–27.

Boyles, Justin G, Paul M Cryan, Gary F McCracken, Thomas H Kunz, and others. 2011. “Economic Importance of Bats in Agriculture.” *Science* 332 (6025): 41–42.

Buchalski, Michael R, Joseph B Fontaine, Paul A Heady III, John P Hayes, and Winifred F Frick. 2013. “Bat Response to Differing Fire Severity in Mixed-Conifer Forest California, USA.” *PloS One* 8 (3). Public Library of Science: e57884.

Carey, Hannah V, Matthew T Andrews, and Sandra L Martin. 2003. “Mammalian Hibernation: Cellular and Molecular Responses to Depressed Metabolism and Low Temperature.” *Physiological Reviews* 83 (4). Am Physiological Soc: 1153–81.

Cooper, Lisa Noelle, Chris J Cretekos, and Karen E Sears. 2012. “The Evolution and Development of Mammalian Flight.” *Wiley Interdisciplinary Reviews: Developmental Biology* 1 (5). Wiley Online Library: 773–79.

Cryan, Paul M. 2011. “Wind Turbines as Landscape Impediments to the Migratory Connectivity of Bats.” *Envtl. L.* 41. HeinOnline: 355.

Fenton, M Brock, and Gary P Bell. 1981. “Recognition of Species of Insectivorous Bats by Their Echolocation Calls.” *Journal of Mammalogy* 62 (2). The Oxford University Press: 233–43.

Forster, Paul I, TH Fleming, and A Valiente-Banuet. 2003. “Columnar Cacti and Their Mutualists. Evolution, Ecology and Conservation.” JSTOR.

Gargas, Andrea, MT Trest, Martha Christensen, Thomas J Volk, and DS Blehert. 2009. “Geomyces Destructans Sp. Nov. Associated with Bat White-Nose Syndrome.” *Mycotaxon* 108 (1). Mycotaxon: 147–54.

Griffin, Donald R, and Robert Galambos. 1941. “The Sensory Basis of Obstacle Avoidance by Flying Bats.” *Journal of Experimental Zoology* 86 (3). Wiley Online Library: 481–506.

Griffin, Donald R, Frederic A Webster, and Charles R Michael. 1960. “The Echolocation of Flying Insects by Bats.” *Animal Behaviour* 8 (3). Elsevier: 141–54.

Gunnell, Gregg F, and Nancy B Simmons. 2005. “Fossil Evidence and the Origin of Bats.” *Journal of Mammalian Evolution* 12 (1-2). Springer: 209–46.

Jepsen, Glenn L. 1966. “Early Eocene Bat from Wyoming.” *Science* 154 (3754). American Association for the Advancement of Science: 1333–39.

Jones, Gareth. 2005. “Echolocation.” *Current Biology* 15 (13). Elsevier: R484–88.

Keeley, Jon E, and Alexandra D Syphard. 2015. “Different Fire–climate Relationships on Forested and Non-Forested Landscapes in the Sierra Nevada Ecoregion.” *International Journal of Wildland Fire* 24 (1). CSIRO: 27–36.

Kunz, Thomas H. 2013. *Ecology of Bats*. Springer Science & Business Media.

Kunz, Thomas H, Elizabeth Braun de Torrez, Dana Bauer, Tatyana Lobova, and Theodore H Fleming. 2011. “Ecosystem Services Provided by Bats.” *Annals of the New York Academy of Sciences* 1223 (1). Wiley Online Library: 1–38.

Lacki, Michael J, Daniel R Cox, Luke E Dodd, and Matthew B Dickinson. 2009. “Response of Northern Bats (Myotis Septentrionalis) to Prescribed Fires in Eastern Kentucky Forests.” *Journal of Mammalogy* 90 (5). The Oxford University Press: 1165–75.

Langwig, Kate E, Winifred F Frick, Jason T Bried, Alan C Hicks, Thomas H Kunz, and A Marm Kilpatrick. 2012. “Sociality, Density-Dependence and Microclimates Determine the Persistence of Populations Suffering from a Novel Fungal Disease, White-Nose Syndrome.” *Ecology Letters* 15 (9). Wiley Online Library: 1050–57.

Lenihan, James M, Raymond Drapek, Dominique Bachelet, and Ronald P Neilson. 2003. “Climate Change Effects on Vegetation Distribution, Carbon, and Fire in California.” *Ecological Applications* 13 (6). Eco Soc America: 1667–81.

Liu, Zhihua, and Michael C Wimberly. 2016. “Direct and Indirect Effects of Climate Change on Projected Future Fire Regimes in the Western United States.” *Science of The Total Environment* 542. Elsevier: 65–75.

Miller, JD, HD Safford, Michael Crimmins, and Andrea E Thode. 2009. “Quantitative Evidence for Increasing Forest Fire Severity in the Sierra Nevada and Southern Cascade Mountains, California and Nevada, USA.” *Ecosystems* 12 (1). Springer: 16–32.

Norberg, UM. 1998. “Morphological Adaptations for Flight in Bats.” *Bat Biology and Conservation (TH KUNZ and PA RACEY, Eds.). Smithsonian Institution Press, Washington DC*, 93–108.

O’Shea, Thomas J, Paul M Cryan, David TS Hayman, Raina K Plowright, and Daniel G Streicker. 2016. “Multiple Mortality Events in Bats: A Global Review.” *Mammal Review*. Wiley Online Library.

Rodrigues, L, L Bach, MJ Duborg-Savage, B Karapandza, D Kovac, T Kervyin, J Dekker, et al. 2015. “Guidelines for Consideration of Bats in Wind Farm Projects—Revision 2014.” *EUROBATS Publication Series*, no. 3.

Schipper, Jan, Janice S Chanson, Federica Chiozza, Neil A Cox, Michael Hoffmann, Vineet Katariya, John Lamoreux, et al. 2008. “The Status of the World’s Land and Marine Mammals: Diversity, Threat, and Knowledge.” *Science* 322 (5899). American Association for the Advancement of Science: 225–30.

Schwartz, Mark W, Nathalie Butt, Christopher R Dolanc, Andrew Holguin, Max A Moritz, Malcolm P North, Hugh D Safford, Nathan L Stephenson, James H Thorne, and Phillip J van Mantgem. 2015. “Increasing Elevation of Fire in the Sierra Nevada and Implications for Forest Change.” *Ecosphere* 6 (7). Wiley Online Library: 1–10.

Smallwood, K Shawn. 2013. “Comparing Bird and Bat Fatality-Rate Estimates Among North American Wind-Energy Projects.” *Wildlife Society Bulletin* 37 (1). Wiley Online Library: 19–33.

Steel, Zachary L, Hugh D Safford, and Joshua H Viers. 2015. “The Fire Frequency-Severity Relationship and the Legacy of Fire Suppression in California Forests.” *Ecosphere* 6 (1). Wiley Online Library: 1–23.

Syphard, Alexandra D, Volker C Radeloff, Jon E Keeley, Todd J Hawbaker, Murray K Clayton, Susan I Stewart, and Roger B Hammer. 2007. “Human Influence on California Fire Regimes.” *Ecological Applications* 17 (5). Eco Soc America: 1388–1402.

Tudge, Colin. 2000. *The Variety of Life*. Oxford University Press Oxford.

USGS. 2016. “White-Nose Syndrome Map.” <https://www.whitenosesyndrome.org/resources/map>.

Verant, Michelle L, Justin G Boyles, William Waldrep Jr, Gudrun Wibbelt, and David S Blehert. 2012. “Temperature-Dependent Growth of Geomyces Destructans, the Fungus That Causes Bat White-Nose Syndrome.” *PLoS One* 7 (9). Public Library of Science: e46280.

Wagtendonk, Jan W van, and Joann Fites-Kaufman. 2006. “Sierra Nevada Bioregion.” *Fire in California’s Ecosystems. University of California Press, Berkeley, California, USA*, 264–94.

Westerling, Anthony L, Hugo G Hidalgo, Daniel R Cayan, and Thomas W Swetnam. 2006. “Warming and Earlier Spring Increase Western US Forest Wildfire Activity.” *Science* 313 (5789). American Association for the Advancement of Science: 940–43.