Modeling Range Shifts for North American Bats under Climate Change

Benjamin Harrison Wheeler

ABSTRACT

Bats are an important component of the world's ecosystems, representing nearly one quarter of all mammalian biodiversity and contributing to the function of the global economy. Little is known, however, about how bat communities may respond to the coming century of climate change. Here I examine how climate change may affect the geographic distribution of bats in North America over the next 70 years under two potential emissions scenarios. I looked for patterns in distribution at a species and a community level. I also looked for *hotspots*, which are locations with high magnitudes of change in number of species and large percentage change per number of species, and examined range shifts for three bats with specific conservation and economic values, the Little Brown Bat, the Brazilian Free-tailed Bat and the Indiana Bat. I found that most North American bats are expected to experience an expansion and northward shift in ranges, with approximately 52 of 88 bats are modeled to experience range increases. There were general increases seen surrounding bodies of water. Coastal regions are modeled to experience moderate decreases, this is particularly true in the Gulf of Mexico, although the east coast as a whole experiences little change. Notable increases can be found in the Midwest as well as across Utah and Nevada. Agricultural losses in Midwest and the South may be particularly large due to shifts of bats northwards. These models are a first step towards understanding changes in bat communities under climate change, which is needed for effective bat conservation and for understanding how ecosystem services they provide might change.

KEYWORDS

Species Distribution Model, Chiroptera, Myotis lucifugus, Myotis sodalis, Tadarida brasiliensis,

INTRODUCTION

Studies examining species' responses to climate change often project significant decreases in the species' geographic ranges at continental and local scales (e.g. Stralberg et al. 2009, Thomas et al. 2004). Thomas et al. (2004) has projected that 15-37% of species could go extinct under mid-range IPCC projections. Projections of such a large extinction event constitute a direct threat to biodiversity and are worrisome to conservationists, as wildlife reserves and protected lands may no longer be inhabited by the species they were designed to protect (Araujo et al. 2004). The loss of species may also be important if those species provided substantial ecological services.

Bats are an important component of the world's ecosystems, contributing to biodiversity as well as to the function of the world economy. Bats comprise over 20% of mammal biodiversity, and include over 1,100 different species around the world (Wilson and Reeder 2005). Bats are important to ecosystem and agricultural functions, including pest control and pollination (Cleveland et al. 2006, Bumrungsri et al. 2008, Boyles et al. 2011, Clare et al. 2011, Kunz et al. 2011). One study in North America estimated that bats provide upwards of $20 billion/year in economic services to the U.S. (Boyles et al. 2011). These benefits, however, may be imperiled by changing climates. Thus the persistence of bat communities is an increasing concern in various areas around the world.

Climate change may cause severe ecological stress for bats. The projected increase in aridity and decrease in precipitation in many regions has been shown to greatly impact the reproductive capabilities of bats (Adams 2010, Frick et. al. 2010). The impact of a potentially large reproductive failure holds huge implications for North America, particularly in the United States. Not only because of the massive financial losses associated with ecological services lost but with the plausible outcome of certain bat species being labeled as endangered. There are currently eight bat species on the Endangered Species List in the US and Mexico (IUCN 2011). Considering the huge economic benefits derived from bats, it is important that we understand bat distributions more fully so that more effective prioritization and conservation plans can be developed for the future, primarily because it has been shown that preventive action is much more cost effective than the actions taken after a species is already at a critical level of endangerment (Wilson et al. 2011). A lack of preventive planning could lead to considerable financial losses through conservation efforts mandated by the Endangered Species Act, potentially to no avail (Wilson et al. 2011).

Species distribution modeling (SDM) provides a framework for projecting future North American bat distribution (Franklin and Miller 2009), but a comprehensive search of distribution modeling yielded only one broad scale study on bats, focused on European bat populations (Rebelo et al 2010). The information needed to make sound decisions ecologically as well as economically regarding Bats in North America is not readily available for conservationist and law makers (Araujo et al. 2004).

I created a species distribution model (SDM) for 88 North American bat species in order to reveal potential shifts in ranges and biodiversity. I examine how climate change may affect the geographic distribution of bats in North America over the next 70 years. I look for patterns in distribution at a species and a community level as well as for *hotspots*, which are locations with a high degree of change in number of species or a large percentage change per number of species. I find an overall shift north in species and a decline in the ranges of northern bat populations as found in the Rebelo et al. (2010) study of European bat populations. I located *hotspots* of change where ecological stress might occur from shifting species ranges.

METHODS

Data collection and preparation

I used the WorldClim data set, with a resolution of 2.5 arc minutes (Hijmans et al. 2005), to measure present climate conditions, defined as average climate data collected from 1950 – 2000. Within the WorldClim dataset I elected to use the Bioclim variables (Hutchinson 2009). These layers are a composite of abiotic factors derived from monthly temperature and rainfall, in order to show annual trends, seasonality and extreme weather conditions and are used frequently for modeling(Beaumont et al. 2007). I selected a subset of Bioclim variables for my analysis by calculating Pearson and Spearman correlation coefficients between all Bioclim variables using 50,000 sampled points from my study region. I used this information to remove redundant variables, eventually selecting eight layers for my analysis: Annual Mean Temperature, Mean Diurnal Range, Temperature Annual Range, Mean Temperature of Wettest Quarter, Annual Precipitation, Precipitation Seasonality, Precipitation of Warmest Quarter. I also included elevation a layer for elevation, also drawn from the Worldclim data set.

I used two future climate scenarios from the Worldclim data set, representing both a "best case" (B2A) and "worst case scenario" (A2A) for the HADLEY Global Climate Model 3(CM3), at 2.5 arc minutes resolution from the Climate Change Agriculture and Food Security website (www.ccafs.org). I clipped the boundaries of all raster files using ArcMap Version 10 (ESRI 2011) to the bounds of contiguous North America, and converted the files from a raster grid format into an ASCII file format (using ArcMap) which was a necessary step for each variable

I downloaded the occurrence points for the bats using a query of 39 different collections and catalogs from The Mammal Networked Information System (MaNIS) Portals. I obtained bat occurrence data from 1950 to the present and only used species with greater than 30 unique occurrences. I overlaid the occurrence data with the present climate data (WorldClim data), and elevation using ArcMap to extract a data table of bat occurrences and climate variables at the location of each occurrence.

Modeling

I used MaxEnt (Phillips et al 2006) to generate species distribution maps using the table of occurrences and climate variables (see Appendix A for details). I generated three separate sets of maps, one set for the present, one set for the future using Hadley CM3 climate scenario A2A and the last for the future using Hadley CM3 climate scenario B2A. For each modeled species, we used the location of all other species as the set of background points from which MaxEnt selected psuedo-absence, a process that helps to correct for sampling bias.

Analysis

To examine and identify the regions that may have largely impacted populations, I looked for regions that the model predicted high influx and/or outflow of species, through expected values and percentage change in each grid cell. I used the raster calculator in ArcMap to do the mathematical operations for each of the two climate scenarios, A2A and B2A. The analysis required three steps: (1) sum for all species, (2) find the difference of the future layers from the present and (3) calculate the absolute change per expected number of species in each grid cell.

Sum species

Then I summed all of the present layers into a single layer, this represents an expected value of the present number of species in each grid cell, where "i" represents the number of species.

$$\sum_{i=1}^{88}[Present]_i \quad , \sum_{i=1}^{88}[Future]_i \quad \textbf{[1]}$$

Calculate a difference

I took the difference of present and future sums of species diversity to create a difference map. These maps show overall species change; decreases or increases regardless of what species. [3]

$$\sum_{i=1}^{88}[Future]_i \; - \sum_{i=1}^{88}[Present]_i \quad [2]$$

Absolute change in relation to biodiversity

I divided the sum of absolute value layers, which represent change (an increase or a decrease in species range), by the sum of the present value layers [2]. This is the change in number of species divided by the present number of species or biodiversity per grid cell [3].

$$\frac{\left(\sum_{i=1}^{88} Abs([Future]_i - [Present]_i)\right)}{\left(\sum_{i=1}^{88}[Present]_i\right)} \; [3]$$

I then examined each of the two climate projections for high change per species and/or high regional increase or decrease, identifying the higher value raster grid squares and identify the geographic locations to which they corresponded. I also examined them in conjunction with agricultural values derived from Boyles et al (2010) as well as physical features and bodies of water (National Geographic et al., 2011) to examine patterns and trends in distribution increases and decreases. For the case study bats, I produced maps looking at their ranges for the present and the future (A2A and B2A), which for the purpose of this analysis is defined as cells with probabilities above 70% and overlaid those probabilities with the stated ranges from the IUCN (IUCN 2011).

RESULTS

In general, species show that more severe climate changes incurred more extreme changes in bats, this held for both increases and decreases. Species richness of bats is modeled to decrease as latitude increases in the present and for both climate scenarios (Fig. 1A, 1B, 1C). The expected values along the West coast of North America are higher than those on the Eastern coast of North America and these trends hold for both climate scenarios.

Coastal regions are expected to experience moderate decreases (loss of 0-2 species), this is particularly true in the Gulf of Mexico (Fig. 1D, 1E). The eastern seaboard of the US experiences little change. Notable increases can be found in the Midwest as well as across Utah and Nevada; these changes are much greater for A2A than for B2A but the focal points remain in the same locations (Fig. 1D, 1E). Mexico as a whole also experienced a large increase in species numbers; with the exception of the Yucatan Peninsula, which shows the largest decreases in North America across most of the peninsula. The higher increases in Mexico were modeled in western and central Mexico, while the eastern coasts of Mexico show decreases.

In the Midwest region of the United States, we found a large expected change per number of current species (Fig. 1F, 1G). The goal of the last two panels was to show net change in species richness, this figure calculates a metric of change equal to the sum of expected increase/decrease for all species, divided by present species richness. This gives an idea of how much change that community will be experiencing whether it is increasing species or decreasing species. These results were similar for the A2A climate models although the B2A scenario changed to a lesser degree. The Midwest had per species changes in the 90% range for A2A.

The West is a very mountainous region and the increasing of temperate conditions higher up on the mountains provides new habitat that was previously uninhabitable due to climactic factors. The mountainous regions in our model are showing a lot of increase many of the *hotspots*, particularly in the west are on mountain landscapes. Some of these points include the El Dorado Mountains and the Black Mountains in Nevada, as well as the Monitor Range in Nevada, the many mountain ranges in Utah and Colorado. There also seem to be a lot of *hotspots* and increases around regions with bodies of water. In Colorado along the Colorado River, and near Lake Mead in southern Nevada as well as the Havasu River, and along the Missouri River in the Upper Midwest. The changes in the Midwest are focused around the Mississippi River, The Missouri River and its headwaters, as well as a number of the lakes in that region.

Central Mexico experiences a large increase of species richness in both scenarios. In our model outputs, Mexico, were found to have a high gross change between three to five species (Fig. 1D, 1E). Mexico is projected to experience a large volume of increases particularly in the mountainous regions of central Mexico where the model predicts large increases in species richness and range for Mexican bats. The regional percentages of Mexico are only moderate as far as percentage of the total population goes, the northern regions of Mexico have higher values, but the percentage change is not as high as the bats to the north in the Midwest and the West. This is primarily due to the large numbers of bats in Mexico that decrease the percentage. Florida also showed higher numbers of species but it is probable that the similarity of Florida to some regions of Mexico created slightly higher values than are true, similar instances of this may be in the northern coast of Alaska as well as in Baffen Bay, Canada based on biodiversity estimates of those regions (Lyons and Willig 1999, Willig et al. 2009) .

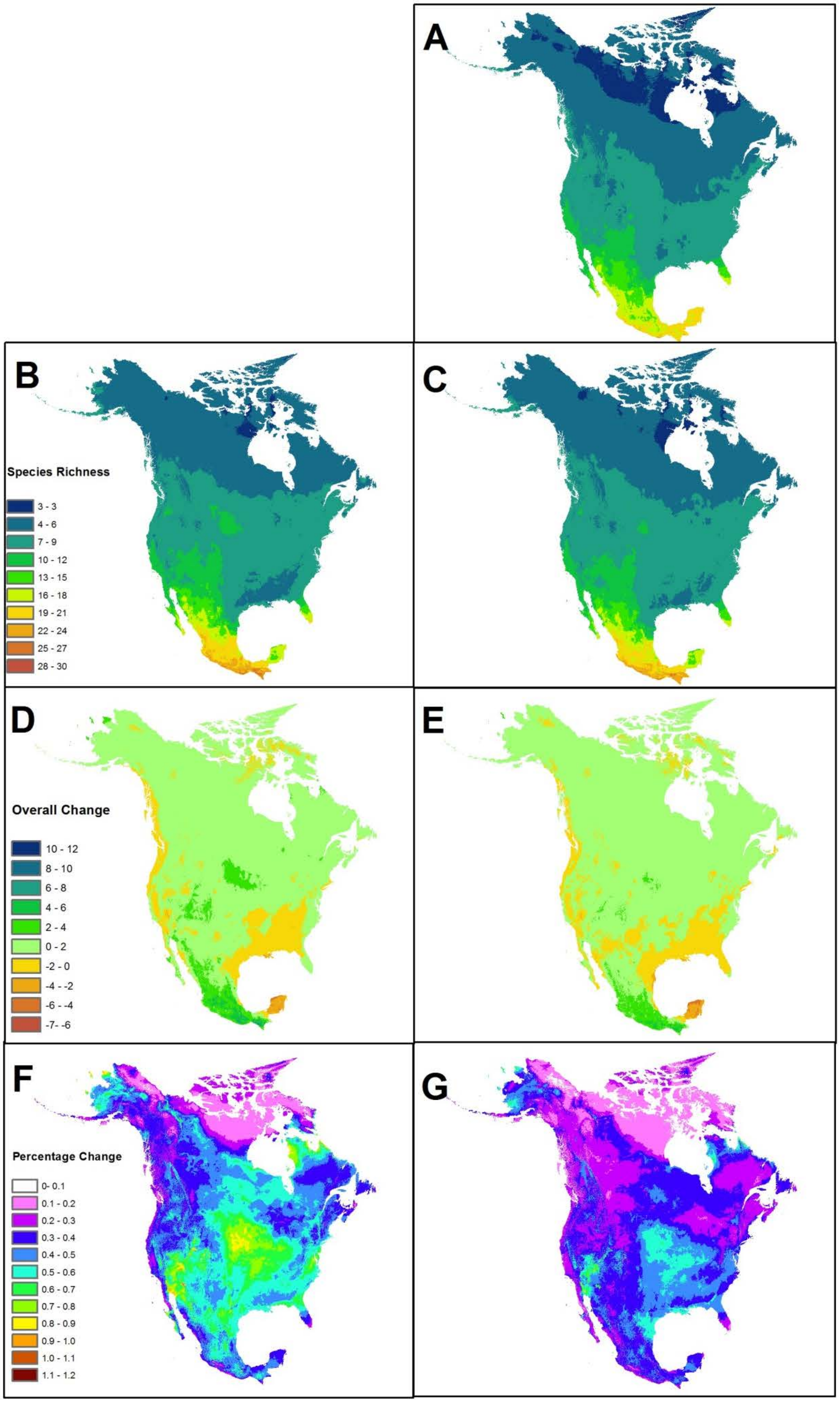

Figure 1: Species richness and changes for the future a) Species Richness for the present b) Species richness for A2A c) Species richness for B2A d)Total species change for A2A e) Total species change for B2A f) Percentage change in species richness for A2A g) Percentage change in species richness for B2A. (Equal Area projection)

With respect to individual species, there are 52 bats increasing in range, when range is defined as cells with a 70% probability of occurrence, and 36 bats decreasing in range for A2A climate scenario (Fig. 2C) and 55 increasing and 33 decreasing in B2A (Fig. 2D). The B2A scenario differs from A2A in magnitude of increase or decrease more so than in numbers of species experiencing both.

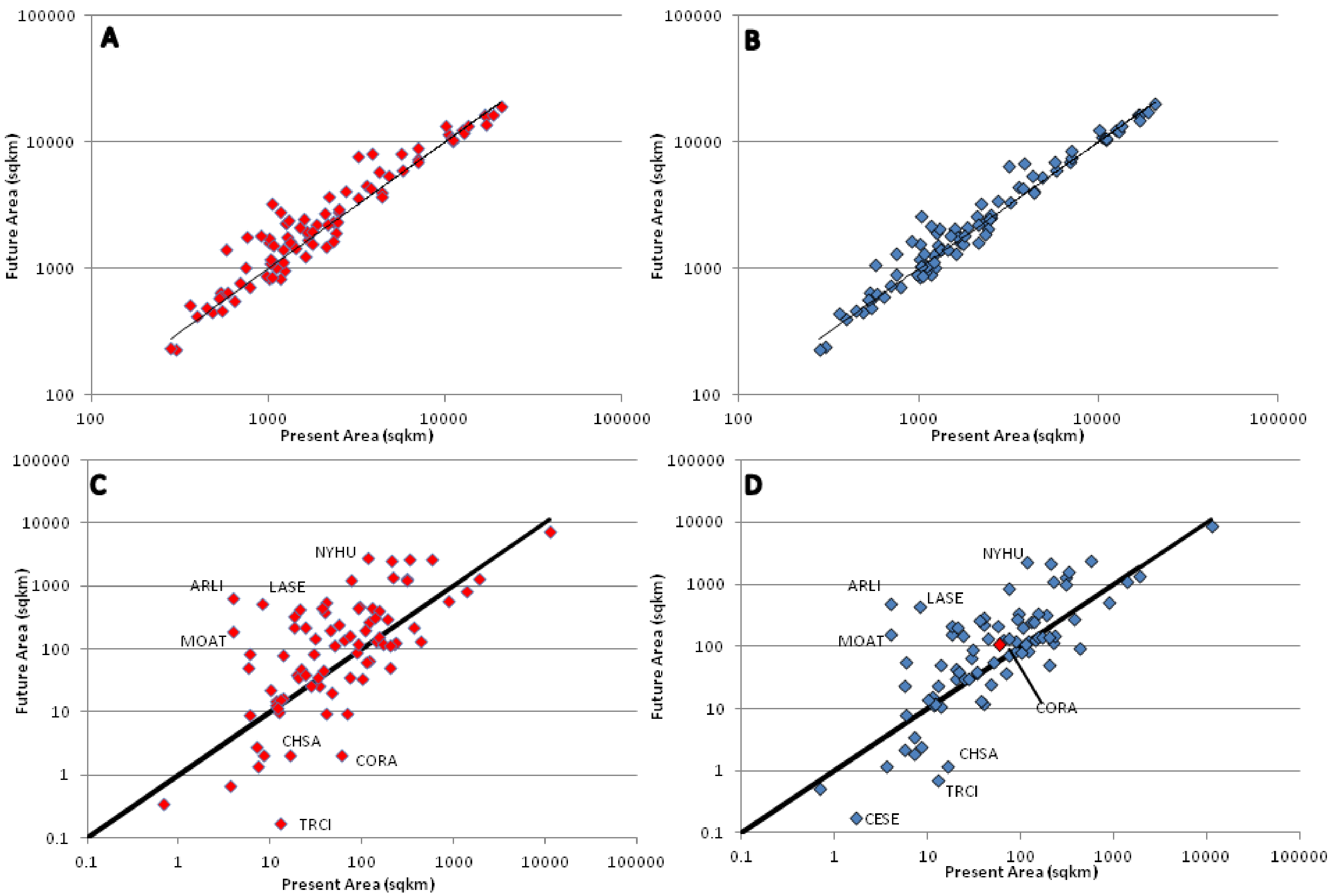

Figure 2: Individual species ranges on log scale. Present area vs. future area in thousands of square kilometers a) A2A at 10% probability threshold b) B2A at 10% probability threshold c) A2A at 70% probability threshold d) B2A at 70% probability threshold. *Artibeus lituratus* (ARLI), *Lasiurus seminolus* (LASE), *Molossus ater* (MOAT), *Nycticeius humeralis* (NYHU), *Trachops cirrhosus* (TRCI), *Centurio senex* (CESE) Chiroderma salvini (CHSA), *Corynorhinus rafinesquii* (CORA). See Appendix C for other species.

Some species showing substantial increases in range are; *Artibeus lituratus* with a 123-160X increase in range, *Lasiurius seminolus* with a 53–63X increase, *Mollosus ater* with an increase of 38–48X, *Nycticeius humeralis* increase of 19-23X. Some species with a substantial decrease percentage wise; *Centurio senex* 90 – 100% decrease, *Chiroderma salvini* a decrease of 87% (A2A)- 93% (B2A), *Trachops cirrhosus* with a 95% (B2A) – 99% (A2A) range contraction, where the low end of all increase and decrease found under the B2A scenario and the high end found under the A2A scenario. *Corynorhinus rafinesquii* is an exception to the rule whereas it increases under B2A (75%), and decreases under A2A (-96%).

Our three case study bat species, the Indiana Bat, the Little Brown Bat, and the Brazilian Free-tailed Bat, all experienced different responses to the changing climate scenarios. The Indiana bat, *Myotis sodalis*, (Fig. 3B) showed a distinct shift in range as well as a distinct decrease in range. The high probability regions of the future ($p > .7$) of the Indiana Bat had very little overlap with its present modeled range (Fig. 3B), with the exception of a region comprised of lower Maine, Vermont, Massachusetts and Pennsylvania. The projections for future distribution shift are away from the Midwest and into Canada. The B2A model for the Indiana Bat has a small region of occurrence in West Virginia. The Little Brown Bat, *Myotis lucifugus,* (Fig. 3A) shows decreasing land availability; it is moving northwards towards Canada and the poles. The model predicts that there will be a contraction within the United States. The model also predicts higher values than should be possible in the high arctic; this is due to values being outside of the training layers for the model (See Appendix B). The Brazilian Free-tailed Bat is showing large increases for both of the model scenarios (Fig. 3C). The bats high probability distribution is shifting northwards to Northern Texas and into Nevada and out of Southern Texas, the probability in Mexico (where they migrate from) is also increasing slightly, the probability is generally increasing across its projected distribution from the International Union for Conservation of Nature (IUCN 2010).

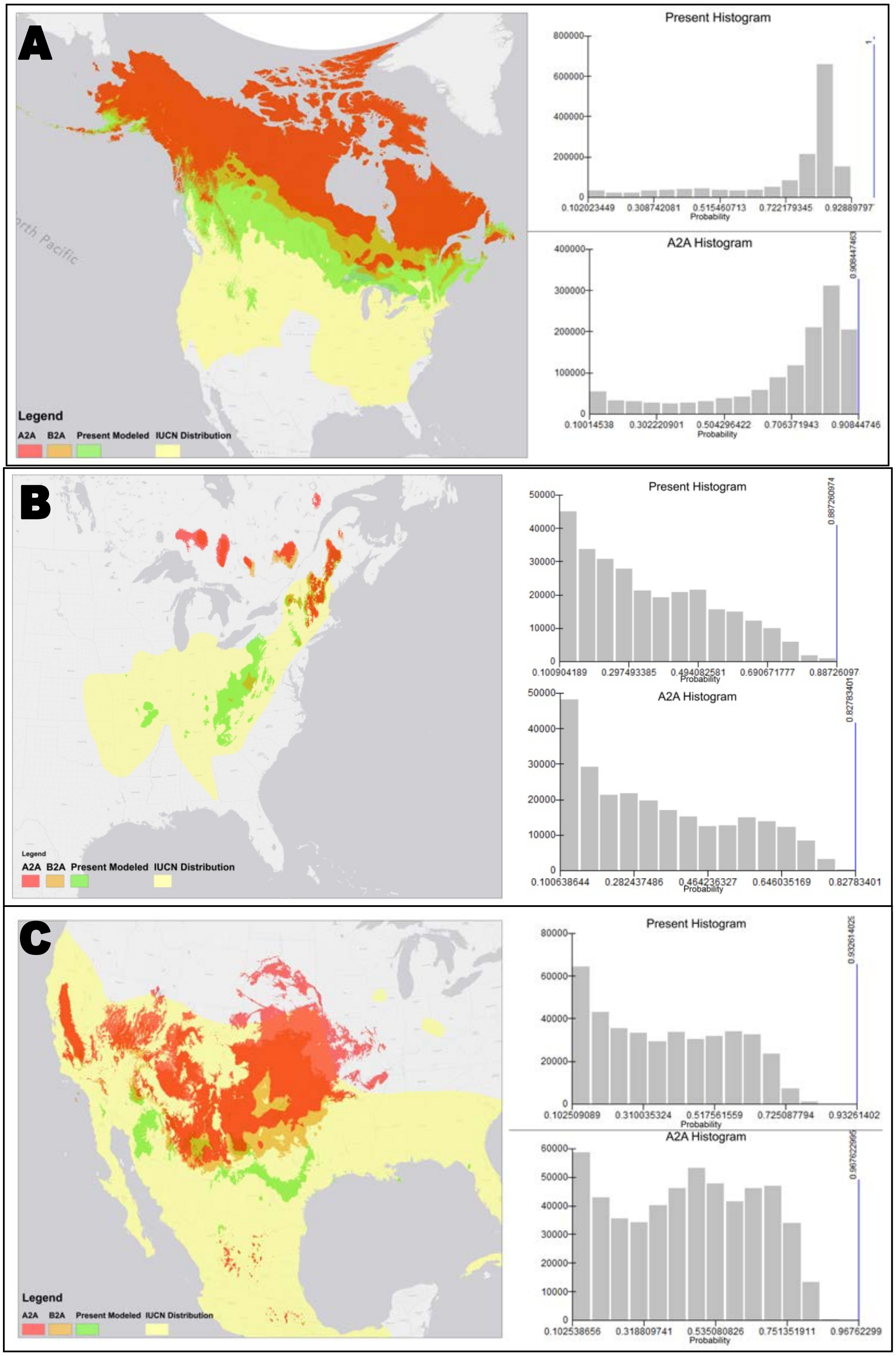

Figure 3. Distributions of case study bats with histograms. A) Little Brown Bat (*Myotis lucifigus*) distribution for future and present, with histograms of SDM layer probability B) Indiana Bat (*Myotis sodalist*) distribution for future and present, with histograms of SDM layer probability C) Mexican Free-tailed Bat (*Tadarida brasiliensis*) distribution for future and present, with histograms of SDM layer probability. (Equal Area projection)

DISCUSSION

My analysis shows *hotspots* in the Midwest, the West, and in Mexico, as well as general shift northward in species richness. A large number of these *hotspots* of high percentage community biodiversity changes are near major inland water bodies, such as Lake Mead in Nevada, the Colorado River and the Missouri and Mississippi Rivers. Locations with large expected change (either in total species richness or species composition) such as these may potentially face ecosystem disruption (Root et al. 2003). There is not a conclusive order-level result with all species increasing or all decreasing with climate change in a uniform way. Some of the bats in my model experience over 100x's range expansion, others are modeled to experience large decreases in the range of 90-95%. The increase in range may be due to greater habitat availability in the Americas as latitude increases in North America there is a larger mass of land available for colonization by new species if those regions become more temperate. With a more temperate climate in the mountains, there is a greater opportunity for more bats in Mexico to increase their ranges into the West and Southwest.

Northward shifts and expanding ranges:

Community-wide patterns in range shifts shows that the majority of bat species are projected to experience range expansion following climate change, with roughly 65% of the species showing range increases and 35% range decreases. This is contrary to models for bats in Europe, Rebelo et al (2010) notes a general decreasing trend of most species with some species experiencing small range increases. This same northward shift has been noted in other taxa (e. g. Huntley et al. 2008). A study of 60 birds in California also modeled increases of biodiversity and range into mountainous regions (Wiens et al. 2009), however most of the birds in this region were modeled to experience decreases in range, this is similar to the responses of bats in California as my analysis suggests decreases in Central California as well as the Mojave Desert, not unlike the decreases found for birds in those same regions.

Agricultural impacts

Studies show that bats have a large impact on agriculture across the United States, a large amount of that value is in the Midwest (Boyles et al. 2011). The high degree of change in the Midwest hold with models of biodiversity expecting that grassland ecosystems will have a large percentage change of biodiversity, and that terrestrial ecosystems will be most affected by land-use change (Sala et al. 2000). The Upper Midwest along the Canadian border is a particularly value dense for bat services to agriculture (Boyles et al. 2011) and disruption to this ecosystem could impact the current agricultural systems that are in place. The wide decreases across the South could also have large implications for the agriculture of that area as well; particularly regarding bats such as the Brazilian Free-Tailed Bat, *Tadarida brasiliensis,* who offer wide spread agricultural services across the lower United States (Cleveland et al. 2006). Although the productivity of the region is not as high as the Midwest, the South has a large amount of agricultural production (Boryan et al. 2011, Han et al. 2012). Regions with decreasing bat populations, like the South, are likely to see increased pest problems due to decreased predation and increased pesticide as a response (Ducummon 2000). Increased pesticide use has both environmental and economic implications for the future, creating health concerns and threats to the human population as well as potentially increasing insecticide resistance in insects and decreasing native fauna (Marrs 1993, Berendse et al. 2004, Colborn and Frederick 2012, McGaughey 2012).

Relationships with water

Limited water supplies may be the most limiting factor for bats as they depend on it heavily during their maternity season and may significantly impact their reproduction in arid locations like Nevada, Colorado and Utah (Adams 2010). There are projected to be increases around many inland water bodies. In the West, areas like the Colorado River, Lake Mead and other water bodies that see increased probability may become focal points for competitive pressures (Walther et al. 2002, Root et al. 2003). There are high percentage increases throughout the Midwest particularly around the Missouri River and the Mississippi River. These areas may experience more extreme competitive pressures. General decreases can be seen regionally on the coasts, reaching above Baja

California to Alaska, and along the entire Gulf of Mexico. It is particularly strong in the Yucatan Peninsula, while the percentage change in the Yucatan was moderate, the absolute number of species predicted to decrease was one of the largest predicted by both models. The environmental stress in that region may be significantly increased, and exacerbated by the loss of habitat from the cutting of tropical forests in that region (Aguilar and Domínguez 1999).

Individual species impacts

Species richness although an excellent tool, cannot describe individual species. The individual species identity matters greatly when it comes to discussing the impacts of decreasing or increasing ranges, as well as the impacts on specific regions. It is important to look at the species particularly those significant to current legislature, economic situation or those facing significant threats to their habitat.

Indiana Bat

In Midwest there will be a high change per species as well as a decrease of the endangered Indiana Bat; this region coincides with a general increase of species richness. The endangered status of the Indiana Bat makes it a priority for conservation. The model suggests that the Indiana Bat, *Myotis sodalis*, may see distinct decreases in area of acceptable habitat and see a shift northwards in distribution. The costs associated with protecting an endangered species can be lessened by present conservation and may have greater impact than conservation actions taken too late (Wilson et al. 2011). This means that prioritizing conservation in a region like the North East (Vermont, Connecticut, Maine and Massachusetts), where the Indiana Bat is predicted to be in the future and has been shown to have acceptable habitat (Carter 2006), becomes extremely important. Focusing continued funding and research within this region for the protection of the Indiana Bat should be a priority.

Little Brown Bat

The Little Brown Bat is particularly of interest because they have been facing the White Nose Syndrome (WNS). Despite the commonness of this species, a decrease in their range like that predicted by the model could potentially produce endangered status. It is noted that common species could be particularly threatened by climate change (Lindenmayer et al. 2011). The Little Brown Bat is projected to have a large contraction of range. This predicted range decrease may be more severe than predicted by the model. The reasoning behind this is that the range is predicted to be habitable in the high arctic where the Little Brown Bat most likely cannot inhabit. There may be other factors that are limiting the upper arctic such as biological productivity or energy and available prey items (Araújo and Guisan 2006). The decrease of the Little Brown Bat's range holds with the findings of Rebelo et al (2010) that northern species face decreases in range due to a decrease of similar habitat and a limit to northward expansion.

Brazilian Free-Tailed Bat

The Brazilian Free-Tailed Bat is a migratory bat, and provides economic services estimated at 12% (~$741,000) of the cotton crop per year in Southern Texas (Cleveland et al. 2006), along with a large portion of the United States. The model distribution of the Brazilian Free-tailed Bat is projected to increase and move farther north, into northern Texas as well as broadening out to the east and west of its current distribution. This may depend on other factors as well, such as the availability of acceptable roosting locations, such as caves and abandoned mines similar to those in southern regions (Watkins 2002). If cotton growing remains feasible as climate shifts, and the bat shifts northward, the region could suffer due to their loss (Cleveland et al. 2006, Boyles et al. 2011).

Limitations

One of the key limitations of this study is the spatial scale; ranges were modeled at 2.5 arc-minutes scale, limiting the scale at which conclusions can be made. The ranges are also modeled based on only a few climactic variables, while in reality there are many more variables affecting the ranges of bats. Another key limitation is that this is not a complete list of North American bats. Not all bat species are represented; more specifically those that were too rare in the museum records (observations < 30) would not be included in this model. This is important because those bats in particular may be especially vulnerable to climate change as they may be experiencing other losses of habitat that further complicate their persistence (Coristine and Kerr 2011). Our model also does not take into account outside effects such as the widespread impacts of large fatalities in hibernating bats from White-Nose Syndrome and wind turbines and the potential implications that those effects might have on future populations. Another limitation regarding observations is that the data available was limited, for the bat species across time, particularly since the number of observations in our dataset peaked around 1948-1951, while there are changes that those locations could have experienced since collection. One of the limitations of our model is that it does not include biotic factors or species interactions; this is a general limitation of SDMs (Araujo et al. 2004, Araújo and Guisan 2006). This makes our outputs represent only acceptable land based on non-biotic factors (fundamental niche), which does not by necessity designate the occurrence of these species. Although some hypotheses about the magnitude of competitive pressures can be made using areas with high percentages of change per species, my MaxEnt model does not take into account competition for limited resources such as water and prey, which could lead to realized ranges being smaller than I predict.

Future research and broader implications

There are several ways in which this analysis could be extended in the future. First, examine *hotspots* of change seeking to better describe or document the complex interactions that may come into play in the future. Hopefully, this study will spur on more in depth studies of individual regions such as the South, the Yucatan Peninsula and the West at a finer scale, looking at changes on a regional scale and considering species interactions and biotic variables. Second, creating finer scale predictions similar to Burns et al. (2003), modelling what the effects climate change may have on the bats in protected lands such as nature preserves, U.S. National Parks and other areas set aside to preserve biodiversity and ecosystem functions. Third, examine the same data through a lens looking at families rather than individual species to determine if bat families are affected by climate change in similar ways.

This study increases the body of knowledge around the future distribution of bats on a continental scale, which is central to creating conservation plans and prioritizing the acquisition of certain parcels of land for reserves over others (Araujo et al. 2004). This study creates a rough diagnostic of regional impacts that can be used to identify areas where increased land protection would be warranted (either in regions expected to experience a large loss, or in regions where there is expected gain) in order to protect biodiversity from potential losses of prime habitat. Land managers and city planners should examine whether or not their region is predicted to undergo a great deal of change and look at other complicating factors surrounding their region in order to make better plans for the future in order to preserve biodiversity. Taking into account the importance of conservation and the importance of having land reserves that include bat ranges, this study elucidates another significant point. A decrease in bat populations and species (through a management failure or natural processes) could mean a significant increase in agricultural pests, which would not only decrease agricultural yield, but also encourage the use of pesticides. An increase in pesticide usage creates dangers of bioaccumulation in humans as well as remaining bat populations. Thus protection of bats, their roosting habitat, their food and their water resources, is imperative, not only because of the economic costs of application of pesticides and increased pesticide resistance, but because of the long term public-health implications as well. The effective protection of bats relies heavily upon their perceived importance in the eye of the policy maker, the conservationist and the eye of the public. Bats are integral to sustainable and profitable agricultural systems in the United States, luckily for the United States economy, my model predicts that bats seem to be increasing in range, but it remains imperative that we protect this essential mammal. Although the outcomes are uncertain, the future looks bright for both biodiversity and ecosystem services of bats.

ACKNOWLEDGMENTS

I would like to thank Justin Kitzes and Audrey Kitzes for their continual mentorship the last three years or so that I have collectively worked with them. I deeply appreciate their help and guidance in career and academia. I would like to thank Prof. Patina Mendez, Melissa Eitzel, Prof. Kurt Spreyer and Dr. Seth Shonkoff for all of their help in this project. I would like to especially thank Patina Mendez and Melissa Eitzel for working very closely with me and helping me develop my academic writing. I also want to thank

Prof. John Radke for his mentorship and guidance in GIS, Adam Smith of the MVZ for his help and expertise in modeling with MaxEnt. I want to thank my parents, Brian and Stephanie Wheeler, for their constant love and affection as well as emotional support, and putting up with me constantly working on my laptop when I spent time at home, My brother David, my sister Rachael and brother-in-law Nick for all their continual support,. I want to thank everyone from my work group B10Kr3w: Katya Cherukumilli, Tara DiRocco, Yuki Ohashi, Shalika Gupta, and Marissa Montjoy. I want to thank Susan Kishi, for her emotional and academic support, who has done more for my education at UC Berkeley than any major advisor should be capable of, ever. I would also like to thank some of my closest friends in ES and fellow GIS enthusiasts Marielle Pinheiro, Uriel Garcia and Jordan Woods (and Sharada). I would like to thank all my friends in ES 196, my roommates Nick, John (and James), the GIF lab, Dr. Merenlender and everyone else that supported me that wasn't mentioned by name.

REFERENCES

Adams, R. A. 2010. Bat reproduction declines when conditions mimic climate change projections for western North America. Ecological Society of America **91**:2437-2445.

Aguilar, R. L. S., and S. R. Domínguez. 1999. Deforestación en la Península de Yucatán , los retos que enfrentar. Madera y Bosques **5**:3-17.

Araujo, M. B., M. Cabeza, W. Thuiller, L. Hannah, and P. H. Williams. 2004. Would climate change drive species out of reserves? An assessment of existing reserve-selection methods. Global Change Biology **10**:1618-1626. doi: 10.1111/j.1365-2486.2004.00828.x.

Araújo, M. B., and A. Guisan. 2006. Five (or so) challenges for species distribution modelling. Journal of Biogeography **33**:1677-1688. doi: 10.1111/j.1365-2699.2006.01584.x.

Beaumont, L. J., a. J. Pitman, M. Poulsen, and L. Hughes. 2007. Where will species go? Incorporating new advances in climate modelling into projections of species distributions. Global Change Biology **13**:1368-1385. doi: 10.1111/j.1365-2486.2007.01357.x.

Berendse, F., D. Chamberlain, D. Kleijn, and H. Schekkerman. 2004. Declining Biodiversity in Agricultural Landscapes and the Effectiveness of Agri-environment

Schemes. AMBIO: A Journal of the Human Environment **33**:499-502. doi: 10.1579/0044-7447-33.8.499.

Boryan, C., Z. Yang, R. Mueller, and M. Craig. 2011. Monitoring US agriculture: the US Department of Agriculture, National Agricultural Statistics Service, Cropland Data Layer Program. Geocarto International **26**:341-358. doi: 10.1080/10106049.2011.562309.

Boyles, J. G., P. M. Cryan, G. F. McCracken, and T. H. Kunz. 2011. Economic Importance of Bats in Agriculture. Science **332**:11-12. American Association for the Advancement of Science. doi: 10.1126/science.1201366.

Bumrungsri, S., E. Sripaoraya, T. Chongsiri, K. Sridith, and P. a. Racey. 2008. The pollination ecology of durian (Durio zibethinus, Bombacaceae) in southern Thailand. Journal of Tropical Ecology **25**:85. doi: 10.1017/S0266467408005531.

Burns, C. E., K. M. Johnston, and O. J. Schmitz. 2003. Global climate change and mammalian species diversity in U.S. national parks. Pages 11474-11477 Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1635115100.

Carter, T. C. 2006. Indiana Bats in the Midwest: The Importance of Hydric Habitats. Journal of Wildlife Management **70**:1185-1190. Allen Press. doi: 10.2193/0022-541X(2006)70[1185:IBITMT]2.0.CO;2.

Clare, E. L., B. R. Barber, B. W. Sweeney, P. D. N. Hebert, and M. B. Fenton. 2011. Eating local: influences of habitat on the diet of little brown bats (Myotis lucifugus). Molecular ecology **20**:1772-1780.

Cleveland, C. J., M. Betke, P. Federico, J. D. Frank, T. G. Hallam, J. Horn, J. D. López Jr, G. F. McCracken, R. A. Medell'\in, A. Moreno-Valdez, and others. 2006. Economic value of the pest control service provided by Brazilian free-tailed bats in south-central Texas. Frontiers in Ecology and the Environment **4**:238–243. Ecological Society of America.

Colborn, T., and S. Frederick. 2012. Developmental Effects of Endocrine-Disrupting Chemicals in Wildlife and Humans. Environmental Health **101**:378-384.

Coristine, L. E., and J. T. Kerr. 2011. Habitat loss , climate change , and emerging conservation challenges in Canada. Atlantic **451**:435-451. doi: 10.1139/Z11-023.

Ducummon, S. L. 2000. Ecological and economic importance of bats. Bat Conservation International Austin TX Pages 4-16.

ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute

Franklin J., J. A. Miller. 2009. Mapping species distributions : spatial inference and prediction. Cambridge University Press, Cambridge; New York.

Frick, W. F., D. S. Reynolds, and T. H. Kunz. 2010. Influence of climate and reproductive timing on demography of little brown myotis Myotis lucifugus. The Journal of Animal Ecology **79**:128-136. doi: 10.1111/j.1365-2656.2009.01615.x.

Han, W., Z. Yang, L. Di, and R. Mueller. 2012. CropScape: A Web service based application for exploring and disseminating US conterminous geospatial cropland data products for decision support. Computers and Electronics in Agriculture **84**:111-123. Elsevier B.V. doi: 10.1016/j.compag.2012.03.005.

Hijmans, R. J., S. E. Cameron, J. L. Parra, P. G. Jones, and A. Jarvis. 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology **25**:1965-1978.

Huntley, B., Y. C. Collingham, S. G. Willis, and R. E. Green. 2008. Potential impacts of climatic change on European breeding birds. PloS one 3:e1439. doi: 10.1371/journal.pone.0001439.

Hutchinson M., Xu T., D. Houlder, H. Nix and J. McMahon. 2009. *ANUCLIM 6.0 User's Guide*. Australian National University, Fenner School of Environment and Society.

IUCN. 2010. IUCN Red List of Threatened Species. Version 2010.4. Retrieved May 3, 2012, from http://www.iucnredlist.org.

IUCN. 2011. IUCN Red List of Threatened Species. Version 2011.2. Retrieved May 3, 2012, from http://www.iucnredlist.org.

Kunz, T. H., E. Braun de Torrez, D. Bauer, T. Lobova, and T. H. Fleming. 2011. Ecosystem services provided by bats. Annals of the New York Academy of Sciences **1223**:1-38. doi: 10.1111/j.1749-6632.2011.06004.x.

Lindenmayer, D. B., J. T. Wood, L. McBurney, C. MacGregor, K. Youngentob, and S. C. Banks. 2011. How to make a common species rare: A case against conservation complacency. Biological Conservation **144**:1663-1672. Elsevier Ltd. doi: 10.1016/j.biocon.2011.02.022.

Lyons, S. K., and M. R. Willig. 1999. A Hemispheric Assessment of Scale Dependence in Latitudinal Gradients of Species Richness. Ecology **80**:2483-2491.

Marrs, T. C. 1993. Organophosphate Poisoning. Pharmaceutical Therapy **58**:51-66.

McGaughey, W. H. . 2012. Insect Resistance to the Biological Insecticide Bacillus thuringiensis. Advancement of Science **229**:193-195.

National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC. 2011. National Geographic World Map, digital topographic basemap of the world. Retrieved on May 3, 2012, from http://www.arcgis.com/home/item.html...5250b3241691b6

Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling **190**:231-259.

Rebelo, H., P. Tarroso and G. Jones. 2010. Predicted impact of climate change on European bats in relation to their biogeographic patterns. Global Change Biology **16**: 561-576.

Root, T. L., J. T. Price, K. R. Hall, and S. H. Schneider. 2003. Fingerprints of global warming on wild animals and plants. Nature **421**:57-60. doi: 10.1038/nature01333.

Sala, O. E., E. Huber-Sanwald, H. A. Mooney, S. C. III, ´. O. Laura F. Huenneke, N. L. P. Juan J. Armesto, E. Berlow, R. B. Jackson, D. H. Wall, M. T. S. Ann Kinzig, B. H. W. Janine Bloomfield, R. L. Rodolfo Dirzo, and M. W. David M. Lodge. 2000. Global Biodiversity Scenarios for the Year 2100. Science **287**:1770-1774. doi: 10.1126/science.287.5459.1770.

Stralberg, D., D. Jongsomjit, C. A. Howell, M. A. Snyder, J. D. Alexander, J. A. Wiens, and T. L. Root. 2009. Re-shuffling of species with climate disruption: A no-analog future for California birds? PloS One **4**:e6825.

Thomas, C. D., A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, Y. C. Collingham, B. F. N. Erasmus, M. F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. S. van Jaarsveld, G. F. Midgley, L. Miles, M. A. Ortega-Huerta, A. T. Peterson, O. L. Phillips, and S. E. Williams. 2004. Extinction risk from climate change. Nature **427**:145-148.

Walther, G.-reto, E. Post, P. Convey, A. Menzel, C. Parmesank, T. J. C. Beebee, J.-marc Fromentin, O. H.-guldberg I, and F. Bairlein. 2002. Ecological responses to Recent Climate Change. Nature **416**:389-395. doi: 10.1038/416389a.

Watkins, F. 2002. An Overview: The North American Bats and Mines Project. Pages 240-246 Proceedings of the 26th Annual British Columbia Mine Reclamation Symposium.

Wiens, J. a, D. Stralberg, D. Jongsomjit, C. a Howell, and M. a Snyder. 2009. Niches, models, and climate change: assessing the assumptions and uncertainties. Proceedings of the National Academy of Sciences of the United States of America 106 Suppl :19729-36. doi: 10.1073/pnas.0901639106.

Willig, M. R., S. K. Lyons, and R. D. Stevens. 2009. Spatial Methods fot the Macroecological Study of Bats. Johns Hopkins Press.

Wilson, H. B., L. N. Joseph, A. L. Moore, and H. P. Possingham. 2011. When should we save the most endangered species? Ecology letters **14**:886-90. doi: 10.1111/j.1461-0248.2011.01652.x.

Wilson, D. E., and D. M. Reeder. 2005. Mammal species of the world: a taxonomic and geographic reference. Volume 1. Third edition.

APPENDIX A: MaxEnt Methods and Settings

I ran 3 different models using MaxEnt, version 3.3.3k, on a Windows 7 machine. The first set modeled was the present projections 1950-2000, then the second and third were projections for HADLEY CM3 respectively. See MaxEnt protocols for code. (I did not include the protocols for the outline). I then amended the Settings on MaxEnt so that they were set using the parameters outlined in the protocols. For the first trial I entered the overlay file (CSV format), in both the Samples and the Environmental Layers. In the Projection Layers I placed the directory of the present Environmental Layers in ASCII format. This produced a projection for the present distribution. For the second trial I entered the overlay file (CSV format), in both the Samples and the Environmental Layers. In the Projection layers I placed the directory of the future Environmental Layers for Hadley CM3 A2A climate projections in ASCII format. For the third trial I entered the overlay file (CSV format), in both the samples and the environmental layers. In the projection layers I placed the directory of the future environmental layers for HADLEY CM3 B2A projections in ASCII format.

The settings on MaxEnt were set apart from the defaults according to this list; Check “Create response curves”, Check “Do jackknife to measure variable importance, “regularization multiplier” set to 2 , “Replicates” set to 5, “Replicated run type” set to “Crossvalidate”, Check “Append Summary results to maxentResults.csv file”, “Apply threshold rule” set to “Equal Sensitivity and Specificity”, “Threads” set to 2-4 depending on machine.

APPENDIX B: Model Regions outside of Training Data

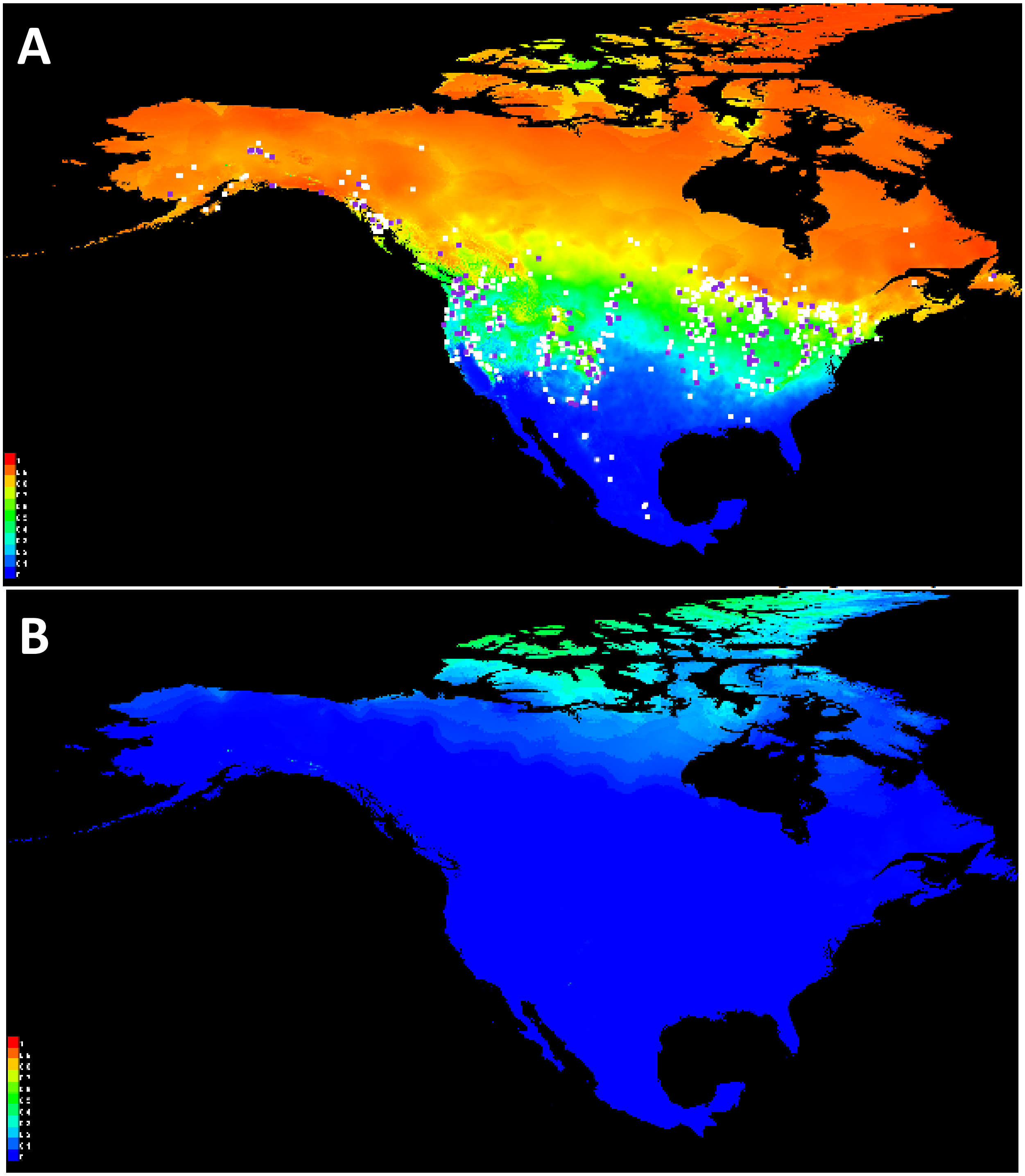

Figure B1: *Myotis lucifugus* Range and regions outside of training data. A) Distribution of sample points and present probability of occurence. B) Distribution of dissimilarity to training data. The data in arctic is dissimilar to any of the sample data and so the model is unable to correctly estimate this region. This may have produced errors in the arctic for other species.

APPENDIX C: List of Species and their Changes in Modeled Range

Table C1: Modeled ranges for A2A compared with present modeled range. Ranges in sqKm'; changes in nX's increase. ***** Change unavailable for some species due to beginning populations having a maximum values below 70%. Many of these species saw drastic increases.

Species	Present Range (sqKm)	Range Modeled under A2A (sqKm)	Difference (A2A -Present) (sqKm)	Change From Present (#X's change)
Anoura_geoffroyi	33622.9335	26073.8216	-7549.1119	-0.224522703
Antrozous_pallidus	74832.5802	34479.1983	-40353.3819	-0.539248838
Artibeus_aztecus	47072.1069	20069.9811	-27002.1258	-0.573633253
Artibeus_hirsutus	120697.71	273775.1268	153077.4168	1.268271095
Artibeus_intermedius	3965.7819	641724.7803	637758.9984	160.8154494
Artibeus_jamaicensis	5862.4602	81995.3074	76132.8472	12.98650133
Balantiopteryx_io	3620.9313	686.1532	-2934.7781	-0.810503668
Balantiopteryx_plicata	39485.3937	379957.3345	340471.9408	8.622731316
Carollia_brevicauda	11380.0698	14923.8321	3543.7623	0.311400753
Carollia_perspicillata	689.7012	343.0766	-346.6246	-0.502572128
Carollia_subrufa	12242.1963	9949.2214	-2292.9749	-0.187300942
Centurio_senex	1724.253	82.85	-1641.403	-0.951950207
Chiroderma_salvini	16552.8288	2058.4596	-14494.3692	-0.875643032
Chiroderma_villosum	11552.4951	12522.2959	969.8008	0.083947302
Choeronycteris_mexicana	189495.4047	301564.3314	112068.9267	0.591407094
Corynorhinus_mexicanus	88626.6042	88856.8394	230.2352	0.002597811
Corynorhinus_townsendii	51037.8888	112700.6631	61662.7743	1.20817643
Dermanura_azteca	65176.7634	136887.5634	71710.8	1.100251014
Dermanura_phaeotis	19828.9095	38596.1175	18767.208	0.946456889
Dermanura_tolteca	20001.3348	34822.2749	14820.9401	0.740997551
Desmodus_rotundus	0	188177.5151	188177.5051	*
Diphylla_ecaudata	29312.301	84396.8436	55084.5426	1.879229563
Eptesicus_furinalis	18449.5071	221970.5602	203521.0531	11.03124609
Eptesicus_fuscus	873506.5698	581857.9136	-291648.6562	-0.333882613
Eumops_perotis	89833.5813	117160.6589	27327.0776	0.304196685
Glossophaga_commissarisi	21553.1625	47516.1091	25962.9466	1.204600327
Glossophaga_leachii	18104.6565	324722.0019	306617.3454	16.93582783
Glossophaga_morenoi	13621.5987	16467.6768	2846.0781	0.208938625
Glossophaga_soricina	0	164676.768	164676.7679	*
Hylonycteris_underwoodi	40692.3708	9434.6065	-31257.7643	-0.768148026
Idionycteris_phyllotis	68452.8441	9263.0682	-59189.7759	-0.864679571
Lasionycteris_noctivagans	130870.8027	457321.1078	326450.3051	2.494447183
Lasiurus_blossevillii	121732.2618	65356.0923	-56376.1695	-0.463116093

Lasiurus_borealis	573141.6972	2677712.863	2104571.166	3.671991021
Lasiurus_cinereus	20691.036	435878.8203	415187.7843	20.06607036
Lasiurus_ega	142250.8725	133971.4123	-8279.4602	-0.05820323
Lasiurus_intermedius	155182.77	155756.7764	574.0064	0.003698905
Lasiurus_seminolus	8276.4144	533998.7279	525722.3135	63.52054019
Leptonycteris_curasoae	93454.5126	479106.4719	385651.9593	4.126627474
Leptonycteris_nivalis	151906.6893	398311.9326	246405.2433	1.622082901
Macrotus_californicus	137422.9641	321291.2359	183868.2718	1.337973409
Macrotus_waterhousii	40347.5202	546349.4855	506001.9653	12.54109206
Micronycteris_megalotis	45175.4286	198126.7365	152951.3079	3.385719021
Molossus_ater	3965.7819	193666.7407	189700.9588	47.83444062
Molossus_molossus	8448.8397	2058.4596	-6390.3801	-0.756361859
Molossus_sinaloae	13966.4493	78221.4648	64255.0155	4.60066937
Mormoops_megalophylla	75177.4308	1261664.197	1186486.766	15.78248622
Myotis_auriculus	91212.9837	448058.0396	356845.0559	3.912217772
Myotis_austroriparius	169321.6446	118532.9653	-50788.6793	-0.299953851
Myotis_californicus	226049.5683	122306.8079	-103742.7604	-0.458938105
Myotis_ciliolabrum	304330.6545	1323761.061	1019430.407	3.349746046
Myotis_evotis	101903.3523	32935.3536	-68967.9987	-0.676798134
Myotis_fortidens	36036.8877	450802.6524	414765.7647	11.50947796
Myotis_grisescens	111386.7438	63126.0944	-48260.6494	-0.433271032
Myotis_keaysi	33278.0829	35679.9664	2401.8835	0.072176138
Myotis_keenii	1395955.229	826299.9911	-569655.2377	-0.408075579
Myotis_leibii	436236.009	132427.5676	-303808.4414	-0.69643137
Myotis_lucifugus	11182987.68	7491077.561	-3691910.121	-0.330136295
Myotis_nigricans	12931.8975	15953.0619	3021.1644	0.233621122
Myotis_occultus	24484.3926	38424.5792	13940.1866	0.569349905
Myotis_septentrionalis	1867710.85	1309351.844	-558359.0057	-0.298953666
Myotis_sodalis	230532.6261	125394.4973	-105138.1288	-0.456066157
Myotis_thysanodes	24139.542	219054.4091	194914.8671	8.074505602
Myotis_velifer	327780.4953	2711505.908	2383725.413	7.272322322
Myotis_volans	369162.5673	216995.9495	-152166.6178	-0.412194061
Myotis_yumanensis	201737.601	49231.4921	-152506.1089	-0.755962736
Natalus_stramineus	37416.2901	46658.4176	9242.1275	0.247008121
Noctilio_leporinus	12069.771	11321.5278	-748.2432	-0.061993156
Nycticeius_humeralis	115007.6751	2802078.131	2687070.455	23.36427072
Nyctinomops_femorosaccus	202772.1528	112357.5865	-90414.5663	-0.445892422
Nyctinomops_macrotis	106731.2607	199670.5812	92939.3205	0.870778813
Peropteryx_macrotis	55693.3719	239124.3902	183431.0183	3.293587945
Phyllostomus_discolor	7241.8626	1372.3064	-5869.5562	-0.810503668
Pipistrellus_hesperus	308468.8617	1240908.062	932439.2005	3.022798461
Pipistrellus_subflavus	212083.119	2541168.376	2329085.257	10.98194551
Platyrrhinus_helleri	7069.4373	2744.6128	-4324.8245	-0.611763612
Plecotus_rafinesquii	59831.5791	2058.4596	-57773.1195	-0.965595767
Pteronotus_davyi	5690.0349	49746.107	44056.0721	7.742671684

Pteronotus_parnellii	40	106696.8226	106656.8226	2666.420565
Pteronotus_personatus	10000.6674	22128.4407	12127.7733	1.212696395
Rhogeessa_parvula	30346.8528	144778.3252	114431.4724	3.770785496
Rhogeessa_tumida	73798.0284	166049.0744	92251.046	1.250047569
Saccopteryx_bilineata	5690.0349	62.2	-5627.8349	-0.989068608
Sturnira_lilium	62	18869.213	18807.213	303.3421452
Sturnira_ludovici	27932.8986	26073.8216	-1859.077	-0.066555105
Tadarida_brasiliensis	220876.8093	1373678.706	1152801.897	5.219207488
Trachops_cirrhosus	12931.8975	171.5383	-12760.3592	-0.986735257
Uroderma_bilobatum	5862.4602	9091.5299	3229.0697	0.550804541

Table C2: Modeled ranges for B2A compared with present modeled range. Ranges in sqKm'; changes in nX's increase. ***** Change unavailable for some species due to beginning populations having a maximum values below 70%. Many of these species saw drastic increases.

Species	Present Range (sqKm)	Range Modeled under B2A (sqKm)	Difference (B2A -Present) (sqKm)	Change From Present (#X's change)
Anoura_geoffroyi	33622.9335	37566.8877	3943.9542	0.117299527
Antrozous_pallidus	74832.5802	73075.3158	-1757.2644	-0.023482611
Artibeus_aztecus	47072.1069	24358.4386	-22713.6683	-0.482529247
Artibeus_hirsutus	120697.71	119562.1951	-1135.5149	-0.009407924
Artibeus_intermedius	3965.7819	493001.0742	489035.2923	123.3137133
Artibeus_jamaicensis	5862.4602	55578.4092	49715.949	8.480390025
Balantiopteryx_io	3620.9313	1200.7681	-2420.1632	-0.668381419
Balantiopteryx_plicata	39485.3937	221627.4836	182142.0899	4.612897906
Carollia_brevicauda	11380.0698	15438.447	4058.3772	0.356621468
Carollia_perspicillata	689.7012	514.6149	-175.0863	-0.253858193
Carollia_subrufa	12242.1963	11664.6044	-577.5919	-0.047180415
Centurio_senex	1724.253	171.5383	-1552.7147	-0.900514426
Chiroderma_salvini	16552.8288	1200.7681	-15352.0607	-0.927458435
Chiroderma_villosum	11552.4951	11149.9895	-402.5056	-0.034841443
Choeronycteris_mexicana	189495.4047	319061.238	129565.8333	0.683741294
Corynorhinus_mexicanus	88626.6042	86112.2266	-2514.3776	-0.028370461
Corynorhinus_townsendii	51037.8888	55406.8709	4368.9821	0.08560272
Dermanura_azteca	65176.7634	129854.4931	64677.7297	0.99234338
Dermanura_phaeotis	19828.9095	43570.7282	23741.8187	1.197333555
Dermanura_tolteca	20001.3348	30362.2791	10360.9443	0.518012643
Desmodus_rotundus	0	102579.9034	102579.9034	*
Diphylla_ecaudata	29312.301	64155.3242	34843.0232	1.188682635
Eptesicus_furinalis	18449.5071	153012.1636	134562.6565	7.293563767

Eptesicus_fuscus	873506.5698	521647.9703	-351858.5995	-0.402811623
Eumops_perotis	89833.5813	118532.9653	28699.384	0.31947278
Glossophaga_commissarisi	21553.1625	39625.3473	18072.1848	0.838493414
Glossophaga_leachii	18104.6565	216138.258	198033.6015	10.93826892
Glossophaga_morenoi	13621.5987	10806.9129	-2814.6858	-0.206634027
Glossophaga_soricina	0	94174.5267	94174.5267	*
Hylonycteris_underwoodi	40692.3708	11836.1427	-28856.2281	-0.70913116
Idionycteris_phyllotis	68452.8441	37052.2728	-31400.5713	-0.458718286
Lasionycteris_noctivagans	130870.8027	245299.769	114428.9663	0.874365893
Lasiurus_blossevillii	121732.2618	85769.15	-35963.1118	-0.295427944
Lasiurus_borealis	573141.6972	2463289.988	1890148.291	3.297872585
Lasiurus_cinereus	20691.036	205502.8834	184811.8474	8.931976504
Lasiurus_ega	142250.8725	129168.3399	-13082.5326	-0.091968031
Lasiurus_intermedius	155182.77	145121.4018	-10061.3682	-0.064835601
Lasiurus_seminolus	8276.4144	444112.6587	435836.2443	52.66003166
Leptonycteris_curasoae	93454.5126	334842.7616	241388.249	2.582949098
Leptonycteris_nivalis	151906.6893	342047.3702	190140.6809	1.25169393
Macrotus_californicus	137422.9641	252847.4542	115424.4901	0.839921412
Macrotus_waterhousii	40347.5202	284238.9631	243891.4429	6.044769088
Micronycteris_megalotis	45175.4286	131569.8761	86394.4475	1.912421203
Molossus_ater	3965.7819	154556.0083	150590.2264	37.97239238
Molossus_molossus	8448.8397	2401.5362	-6047.3035	-0.715755502
Molossus_sinaloae	13966.4493	51118.4134	37151.9641	2.660086562
Mormoops_megalophylla	75177.4308	855118.4255	779940.9947	10.37466945
Myotis_auriculus	91212.9837	270344.3608	179131.3771	1.963880249
Myotis_austroriparius	169321.6446	138431.4081	-30890.2365	-0.18243525
Myotis_californicus	226049.5683	112872.2014	-113177.3669	-0.500674997
Myotis_ciliolabrum	304330.6545	1269211.882	964881.2272	3.170502915
Myotis_evotis	101903.3523	82166.8457	-19736.5066	-0.193678678
Myotis_fortidens	36036.8877	261081.2926	225044.4049	6.244834648
Myotis_grisescens	111386.7438	110470.6652	-916.0786	-0.008224305
Myotis_keaysi	33278.0829	38081.5026	4803.4197	0.144341839
Myotis_keenii	1395955.229	1096301.275	-299653.9535	-0.214658713
Myotis_leibii	436236.009	95203.7565	-341032.2525	-0.781760894
Myotis_lucifugus	11182987.68	8798885.56	-2384102.122	-0.213190087
Myotis_nigricans	12931.8975	23672.2854	10740.3879	0.830534568
Myotis_occultus	24484.3926	30705.3557	6220.9631	0.254078719
Myotis_septentrionalis	1867710.85	1346918.732	-520792.118	-0.278839799
Myotis_sodalis	230532.6261	149581.3976	-80951.2285	-0.351148685
Myotis_thysanodes	24139.542	149238.321	125098.779	5.182317834
Myotis_velifer	327780.4953	1596163.882	1268383.386	3.869612147
Myotis_volans	369162.5673	281151.2737	-88011.2936	-0.238407957
Myotis_yumanensis	201737.601	49746.107	-151991.494	-0.753411824
Natalus_stramineus	37416.2901	13036.9108	-24379.3793	-0.65157126
Noctilio_leporinus	12069.771	11836.1427	-233.6283	-0.019356482

Nycticeius_humeralis	115007.6751	2309077.056	2194069.381	19.07759095
Nyctinomops_femorosaccus	202772.1528	141004.4826	-61767.6702	-0.304616139
Nyctinomops_macrotis	106731.2607	206360.5749	99629.3142	0.933459546
Peropteryx_macrotis	55693.3719	209791.3409	154097.969	2.76689961
Phyllostomus_discolor	7241.8626	1886.9213	-5354.9413	-0.739442543
Pipistrellus_hesperus	308468.8617	1017908.272	709439.4105	2.299873662
Pipistrellus_subflavus	212083.119	2137881.833	1925798.714	9.08039604
Platyrrhinus_helleri	7069.4373	3430.766	-3638.6713	-0.514704515
Plecotus_rafinesquii	59831.5791	104638.363	44806.7839	0.748881854
Pteronotus_davyi	5690.0349	23157.6705	17467.6356	3.069864405
Pteronotus_parnellii	40	42198.4218	42158.4218	1053.960545
Pteronotus_personatus	10000.6674	13723.064	3722.3966	0.372214818
Rhogeessa_parvula	30346.8528	90400.6841	60053.8313	1.978914641
Rhogeessa_tumida	73798.0284	132770.6442	58972.6158	0.799108283
Saccopteryx_bilineata	5690.0349	2229.9979	-3460.037	-0.608087131
Sturnira_lilium	62	18183.0598	18121.0598	292.2751581
Sturnira_ludovici	27932.8986	29504.5876	1571.689	0.056266592
Tadarida_brasiliensis	220876.8093	1111053.569	890176.7598	4.030195667
Trachops_cirrhosus	12931.8975	686.1532	-12245.7443	-0.946941027
Uroderma_bilobatum	5862.4602	8062.3001	2199.8399	0.375241763