A Dearth of Data on the Mammals of the Madrean Archipelago: What We Think We Know and What We Actually Do Know

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Abstract—*The Madrean Archipelago harbors one of the most diverse mammalian communities in North America. We used the Web of Science literature search tool to assess the diversity of peer-reviewed publications on mammals in Arizona and New Mexico as an indicator of publications in the region. The number of publications of all mammals was lower than expected with a mode of 0 and a median of 1. Species were not studied equally in Arizona with most measures suggesting a disproportionately large number of publications on the Order Artiodactyla and small numbers of publications on the Orders Rodentia and Chiroptera. Large mammals and those found in many Arizona counties tend to be the subject of more publications. Despite the great diversity of the region, a dearth of published data on mammalian species is evidenced within the Madrean Archipelago, especially among the Rodentia and Chiroptera.*

Introduction

The Madrean Archipelago of Southwestern United States and Northwestern Mexico is a region of incredible biodiversity (Gehlbach 1993). Recent incursions by jaguars (*Panthera onca*: Brown and Gonzales 2000) and the reintroduction of Mexican gray wolves (*Canis lupus*: Holaday 2003) further promote the image of the region as a last refuge for biodiversity. The region consists of >40 montane islands that harbor great mammalian diversity. This diversity of mammals is in part explicable by island biogeographic theory (Lomolino et al. 1989; Patterson 1995) as well as by the absence of Pleistocene glaciation (Brown and Davis 1995). As a result, southeastern Arizona possesses the greatest mammalian diversity north of Mexico (Turner et al. 1995). Herein, we use a common electronic library resource to assess our current state of knowledge on the mammals of the region by focusing on publications produced on the mammals of Arizona.

Materials and Methods

Literature Search

Data on the mammals of Arizona were gleaned from published literature sources abstracted by the Science Citation Index using the Web of Science literature search tool that covers publications from 1945 to April 15, 2004, and searches titles, key words, and abstracts terms entered into the search. For each of 138 mammalian species, we used the scientific names found in Hoffmeister (1986), Findley et al. (1975), and Kays and Wilson (2002). Our search protocol used the "Topic" search option into which we entered the following 3 combinations: scientific name, the scientific name and Arizona, and the scientific name and New Mexico. In the case of recently used synonyms, we repeated these searches with the synonyms. While these searches returned most of the research with which we were familiar, we know that some publications did not appear due to a lack of congruence between our keywords and the search engine. The relative numbers of publications and the general trends are expected to remain similar. Gray literature is not included in our review as its peer-reviewed status is unknown and the works are not generally available to the public.

Variables

We recorded total number of publications for each species as well as number of publications on each species in Arizona and New Mexico. From these data, we calculated the percentage of all publications that were conducted in Arizona. Our proxy for body size was the midpoint of body masses; female body mass was used in sexually dimorphic species (Kays and Wilson 2002). We tallied the number of counties in Arizona (maximum = 15) occupied by each species (Hoffmeister 1986). We used the range maps in Kays and Wilson (2002) to estimate the proportion of a species' range that was found in Arizona. Endemic species received a value of 100 with other values rounded downward to the nearest multiple of 10. The proportion of a species range that is found in Arizona was used as an expected proportion of publications that should be produced from Arizona.

Data Analyses

We transformed data where possible to meet the normality assumption of parametric tests; non-parametric tests were used where normality could not be approached or attained. Means $\pm$ 1 S.E. are provided throughout the text.

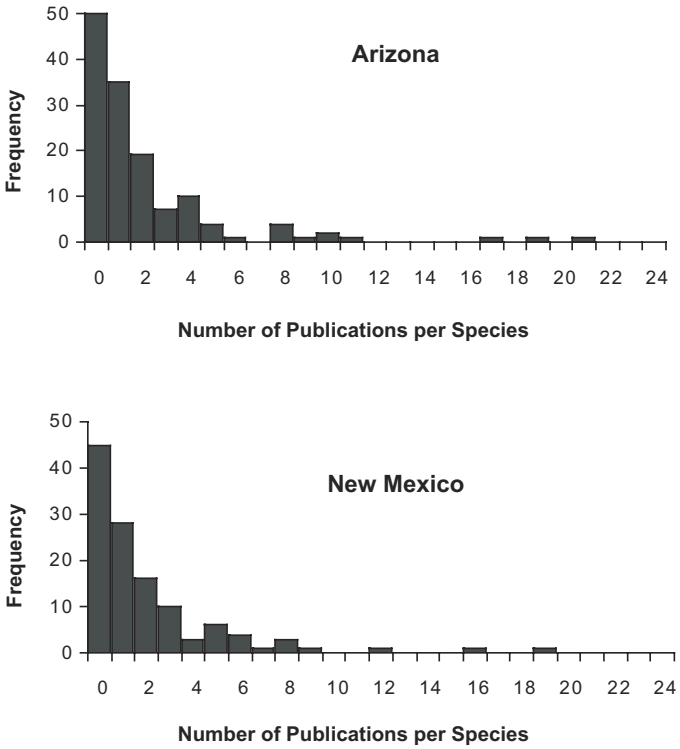

Figure 1—Frequency distribution of number of publications per mammalian species for Arizona and New Mexico.

Results

A Dearth of Data

The most common number of publications for a mammal species in Arizona and New Mexico was 0 publications (figure 1)! The median number of publications per mammal species for each State was only 1 paper. Using the percent range of a species that falls in Arizona as an indicator of the expected frequency of publications yields a similar conclusion. Publications on the mammals of Arizona average about 6.053% of the total publications across all species; this is significantly less than the estimated 10.871% of the range of each species that is found in Arizona ($t = 2.82$, $df = 233.9$, $P < 0.005$). These results collectively suggest that Arizona mammals are understudied relative to their occurrence in the State.

Is It Just Arizona?

Arizona is not alone in the Madrean Archipelago in its relative lack of studies on mammals because the mean number of publications per species for the same subset of mammals is nearly identical between New Mexico and Arizona (2.07 $\pm$ 0.28 papers, 2.09 $\pm$ 0.29 papers, respectively; $t = 0.691$, $df = 247$, $P = 0.945$). The frequency distributions of publications in the two States (figure 1) did not differ (Smirnov's $D = 0.04$, $P = 0.499$). This dearth of papers was not specific to a single taxa as no Orders differed between Arizona and New Mexico in the number of publications/species (Carnivora: $U = 283$, $P = 0.317$, Insectivora: $U = 18.5$, $P = 0.732$, Chiroptera: $U = 390.5$, $P = 0.636$, Rodentia: $U = 1{,}735$, $P = 0.115$, Lagomorpha: $U = 7.5$, $P = 0.571$, Artiodactyla: $U = 37.5$, $P = 0.107$).

Is Our Knowledge of Mammalian Species Unrelated to Taxa?

Our scant knowledge of mammals in the Madrean Archipelago does not extend equally to all Orders (1-way ANOVA: $F_{5, 139} = 9.847$, $P < 0.0001$). Publications on Artiodactyla are more common than all other Orders by nearly a factor of 10; other Orders averaged <2.5 publications per species and did not differ from each other (figure 2: All Tukey-Kramer post hoc comparisons $q > 7.4$, $P < 0.0001$). Similarly, an analysis of the Orders comparing data on the proportion of a species range in Arizona suggests that the Order Rodentia is most understudied in Arizona ($U = 3813.5$, $P < 0.0001$). The Orders Carnivora ($U = 262$, $P = 0.634$), Insectivora ($U = 17.5$, $P = 0.995$), Chiroptera ($U = 446$, $P = 0.406$), Lagomorpha ($U = 12$, $P = 0.984$), and Artiodactyla ($U = 12$, $P = 0.3636$) are studied about as expected based upon the percentage of the range of each species that occurs within Arizona. Within Rodentia, 3 of the 4 families with at least 5 species in Arizona were studied less than expected (Cricetidae: $U = 366.5$, $P = 0.0265$, Heteromyidae: $U = 209$, $P < 0.001$, Sciuridae: $U = 276.5$, $P = 0.0037$); only voles (Arvicolidae: $U = 17$, $P = 0.397$) were studied as expected based upon the amount of range that occurs in Arizona.

Finally, the frequency distributions across the Orders, after summing all publications within each Order, differed between "Total Publications" and "Arizona Publications" (Smirnov $D = 0.833$, $P = 0.026$) with the principal difference being a lower frequency of publications on Rodentia in Arizona (figure 3). The frequency distribution of the number of Arizona publications by Order predicted by the frequency of species within that Order in Arizona was significantly different (figure 3: $\chi^2 = 27.10$, $df = 5$, $P < 0.0001$) with the primary contributions coming from a 523.3% overabundance of publications on Artiodactyla and a 23.4% shortage of publications on Chiroptera.

What Factors Influence the Frequency of Publication?

The number of publications on a species in Arizona was not predicted by the percent of range within Arizona ($r = 0.055$, $F_{1,137} = 0.418$, $P = 0.519$). Publications were more likely to occur when a species occupied a greater number of Arizona counties ($r = 0.273$, $F_{1,137} = 10.98$, $P = 0.001$). Body size of a species was not an important predictor of the number of Arizona counties in which a species was found ($r = 0.088$, $F_{1,137} = 1.062$, $P = 0.305$); however, body size was an excellent predictor of number of publications from Arizona ($r = 0.326$, $F_{1,137} = 16.178$, $P < 0.0001$). Only body size ($t = 3.86$, $P < 0.0001$) and the number of Arizona counties occupied ($t = 3.13$, $P = 0.002$) entered a stepwise multiple regression model to predict the number of Arizona publications for a species ($R^2 = 15.4\%$; $F_{1,137} = 13.49$, $P < 0.001$: Number of Arizona Publications = 0.235 + 0.000032 Body Mass in Grams + 0.183 Number of Arizona Counties); percent area did not enter the model.

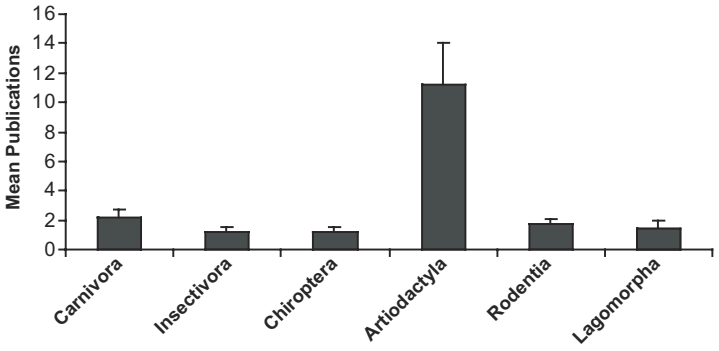

Figure 2—Mean (+ 1 S.E.) number of publications per species for each of the mammalian Orders found in Arizona.

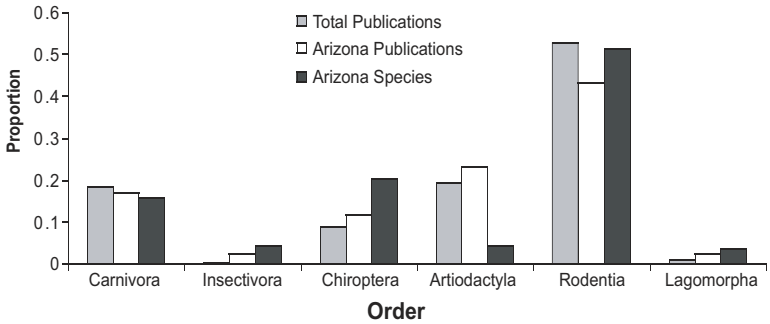

Figure 3—Proportion of total and Arizona publications as well as species for each of the mammalian orders found in Arizona.

Discussion

Our analyses suggest a "dearth of data" exists in the peer-reviewed literature despite the incredible mammalian diversity of the Madrean Archipelago (Turner et al. 1995). Some of this apparent dearth of data may be an artifact of the inability of our searches to identify papers using our literature search tool (Suarez-Almazor et al. 2000). We would not expect such biases to influence the general patterns that we found in our investigations. Papers that were missed in our search demonstrate the need for careful consideration of words when providing titles, abstracts, and keywords with submitted manuscripts. If one of the most popular and powerful search engines of scientific abstracts failed to detect a publication, the conservation value of our research is not fully realized and the funding dollars not fully maximized. Researchers that rely solely on web based searches of scientific journals are not likely to represent the majority, but these technologies continue to increase in popularity (Walters and Wilder 2003). The abundance of studies for some species and the shortage of studies for others can be influenced by a number of factors. Potential proximate causes for such divergence from expected values include the amount of funding available, proclivity of researchers to publish, legal status of the species, and the accessibility of study organisms. Rodents are among the most difficult taxa to examine due to small body size, secretive habits (subterranean, nocturnal, arboreal), and propensity to hibernate or enter torpor. After rodents, Chiroptera are the second most diverse order, comprising almost one quarter of all mammal species. In Arizona there are 28 different species of bats, due in large part to the diversity of available habitats created by the Madrean Sky Islands and surrounding arid desert seas (Hoffmeister 1986). Flight is the unique trait that distinguishes bats from all other mammals. However, flight, plus their nocturnal life style, make bats particularly difficult to study. When compared to a similar-sized terrestrial mammal, bats have larger home ranges and use flight to cross unsuitable habitat to find roosts, food, and drinking water. Bats are also unique because they are long-lived for their size and have low reproductive potential. As a result, impacts on populations can have long-term implications (Findley 1993). These characteristics of rodents and bats likely "predispose" them to a dearth of publications.

Technological limitations are also likely influential in the disproportionate publication rates. Prior to the 1990's, the study of Arizona bats was conducted primarily at roosts or where they obtain drinking water, because we could more easily capture them using either harp traps or mist nets across fly-ways. Recently, the innovation of affordable ultrasonic detectors has allowed us to understand more details of their life history and behavior (Fenton 1999). Modern technology has also provided bat and rodent researchers with small, light-weight radio transmitters that allow greater knowledge of movement patterns; however, this technology is still limited by short battery life of transmitters. In particular, Chiropteran studies are labor-intensive, often plagued by low sample size and difficult to conduct due to the nature of monitoring animals that can quickly fly across rugged terrain.

In 1990, Arizona voters passed an initiative to provide monies from State lottery revenues to wildlife and conservation efforts through the Arizona Game and Fish Department (AGFD) Heritage Program. Some of these funds have been used to study mammals throughout the State plus fund positions within AGFD. These positions were often quite progressive as in the establishment of a biologist to monitor bat research and oversee development of one of the first "Bat Conservation Strategic Plans" in the United States in recognition of the paucity of knowledge on even the most common bat species. This program has increased the volume of "gray literature," but has not yet impacted the data available to researchers through peer-reviewed journals. We can and need to do better. Often research has been conducted on mammals in Arizona that includes long-term monitoring of bat roosts, small mammal community surveys, road kill surveys, and track counts; however, these data typically are not published. We must strive to design and conduct our studies using proper scientific methodology, attempt to accurately represent the diversity of mammals in these studies, and endeavor to disseminate the resultant knowledge to scientists through peer-reviewed and abstracted outlets. Perhaps a new journal devoted to the natural history of the Madrean Archipelago is needed.

Most striking is the large number of species for which we have no peer-reviewed publications. This paucity of data occurs in one of the global evolutionary hotspots (Spector 2002) and a center of mammalian diversity (Turner et al. 1995); the conservation value of the region is clear. The

Madrean Archipelago has played a prominent role in the re-establishment of carnivores in North America due in part to its rugged and diverse topography and location that provides connectivity in the mountains of Western North America. Despite the dearth of data, the region has provided significant insights into the ecology of competition and community diversity in desert rodents (Brown et al. 2002), island biogeography (Lomolino et al. 1989), the complexities of mutualism in bats (Fleming et al. 2001), and the spread of disease such as the Sin Nombre Virus in rodents (Glass et al. 2002). The mammals of the Madrean Archipelago most certainly have much more to teach us but we must attend the lectures.

Acknowledgments

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