Biogeographical distributions of trickster animals

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Abstract

Environments have facilitated diversification in human cultures, including folklore. Previous studies show that folklore may transmit folk-zoological knowledge about the local environment. However, it remains unclear whether and how environmental factors are related to animal distributions of folklore. By systematically and quantitatively analyzing large databases in both ecology and folkloristics, we compare the distributions of real animals and those of trickster animals, a common folkloristic motif. The result shows that the distribution of trickster animals is restricted by the presence of trickster animals in the neighborhood, and, more importantly, the presence of real animals. Given that the distributions of real animals are restricted by environmental factors, annual mean temperature and precipitation, these environmental factors indirectly restrict the distribution of trickster animals. This study demonstrates the importance of combining perspectives from both human science and ecology to understand nature's contribution to people.

Significance

Human scientists and ecologists have documented numerous cases of environmental factors affecting both the distribution and diversity of human cultures and biological organisms, respectively. This study examines the relationship between the environment, animals in nature, and animals in folklore. based on a systematic and quantitative analysis of three key databases, we demonstrated that annual mean temperature and annual precipitation can affect animal distributions in their natural habitat, which restricts trickster animals in folklore. Our results, therefore, emphasize the importance of interdisciplinary research on human cultures from perspectives of both ecology and human science.

Introduction

One of the hallmarks of human societies is the abundant diversity of cultures, i.e., socially transmitted behavior or information (Foley and Mirazón Lahr, 2011) across history (Basalla, 1988) and geography (Collard and Foley, 2002). Natural environments are a major source of cultural diversity including material (Osborn, 1999) and non-material cultures (Talhelm et al., 2014; Botero et al., 2014; Nakadai, 2023). Folklore (see detailed definition in SI 1) is another example of a non-material culture which is affected by the environments. Commonly perceived as a collection of traditional stories that transmit cultural identity among social groups, folklore is also vital for ecological knowledge of the local environment (Scalise Sugiyama, 2001; Smith et al., 2017). Examples include folk-biological knowledge or local's understanding of harmful animals (Scalise Sugiyama, 2006), pairs of wild animals, or those of wild and domestic animals (Nakawake and Sato, 2019). Descriptions of animals in folklore have been studied worldwide (Berezkin, 2014).

For decades, the determinants of animal distribution in nature have been a topic in biogeography (Lomolino et al., 2010). Animal distributions depend on biotic and abiotic factors (Lomolino et al., 2010). Therefore, it is reasonable to posit that animal distributions in folklore reflect the distributions of real animals and their environmental background. However, the ecological factors determining the animal distributions in lore have been under-researched. In this study, we addressed determinants of animal distribution in folklore by statistically analyzing the databases of tricksters and real animals (Fig. 1). We used tricksters (see detailed definition in SI 1) because they are common characters in folklore worldwide (Leeming, 2022; Pache, 2012).

Methods

In this study, we compiled data on animal tricksters' distributions, real animals' distributions, and climate conditions from Berenzkin's world myth database (Berezkin, 2022), Global Biodiversity Information Facility (GBIF) (GBIF.org, 2020), and WorldClim 2.1 (Fick and Hijmans, 2017), respectively. In the myth database, we extracted motifs entitled "Trickster–X" (m29a – m29i) and "Trickster is a X" (m29l –m29y) on July 2022, where X represents the following common names of animals: anteater, badger, ground squirrel, hawk, mink, mouse, opossum, owl, porcupine, rabbit/hare, raccoon, rat, raven/crow, skunk, spider, and wren. We matched the scientific names of real animals to common names through Wikipedia (Supporting data set). We obtained the distributions of these species using the scientific names in GBIF. From WorldClim 2.1, we retrieved the annual mean temperature and annual precipitation because they classify the environments into nine (+1 as an outlier) classes of Whittaker's biome (Whittaker, 1970).

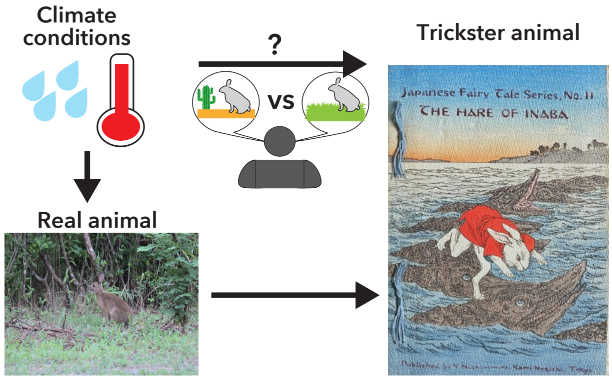

Figure 1: Constraints on the trickster animal distributions

Schematic representations of the manuscript show two environmental conditions – annual mean temperature and annual precipitation – that affect the distribution of real and potentially trickster animals. The real animal distributions are the necessary condition for the presence of trickster animals. Here, we show Japanese hare *Lepus brachyurus* (Photo by Dr. Abby Darrah https://www.inaturalist.org/observations/105058298, CC-BY) and "*The Hare of Inaba*" (Illustration by Eitaku Kobayashi) as examples of a real hare and trickster hare, respectively. The image of *The Hare of Inaba* is from the library of the Open University of Japan.

The intensity of data collection of tricksters and real animals was likely to differ across species and locations. Therefore, we converted the coordinates data into hex grid indices, and analyzed the presence of trickster and real animals in each grid. We used the climate data at the center point of each grid as representative values. If the climate data at a center point were not available, we used the mean values in the focal grid.

Results

Environmental constraints on animal distributions

We began investigating the climate conditions' possible effects on the distributions of real and trickster animals, respectively (bottom panels of Fig. 2). We selected annual mean temperature and annual precipitation as environmental factors to focus on, which classified the climate conditions into nine Whittaker's biome classes (Whittaker, 1970). Before analyzing the distributions of the trickster animals, we investigated whether these two climate conditions restricted real animal distribution. We compared the fractions of the biome classes between each category of real animals and terrestrial areas (i.e., the null model) using the chi-squared test. The left column of Table 1 shows that 12 of the 16 real animals' distributions are different from the null model, suggesting that the annual mean temperature and annual precipitation restrict many animals' distribution. The exceptions were hawks, owls, rabbits, and spiders, which are found on all continents except for Antarctica (see the green and blue areas on the world maps of Fig. 2). In contrast, only four animals (i.e., minks, opossums, ravens, and skunks) differed in the fractions of the biome classes between the tricksters and the null model (the middle column of Table 1). These analyses, therefore, provide evidence that annual mean temperature and annual precipitation restrict the real animal distributions but these environmental constraints are less evident on the trickster animal distributions. However, this may be because of differences in amounts of data (see SI

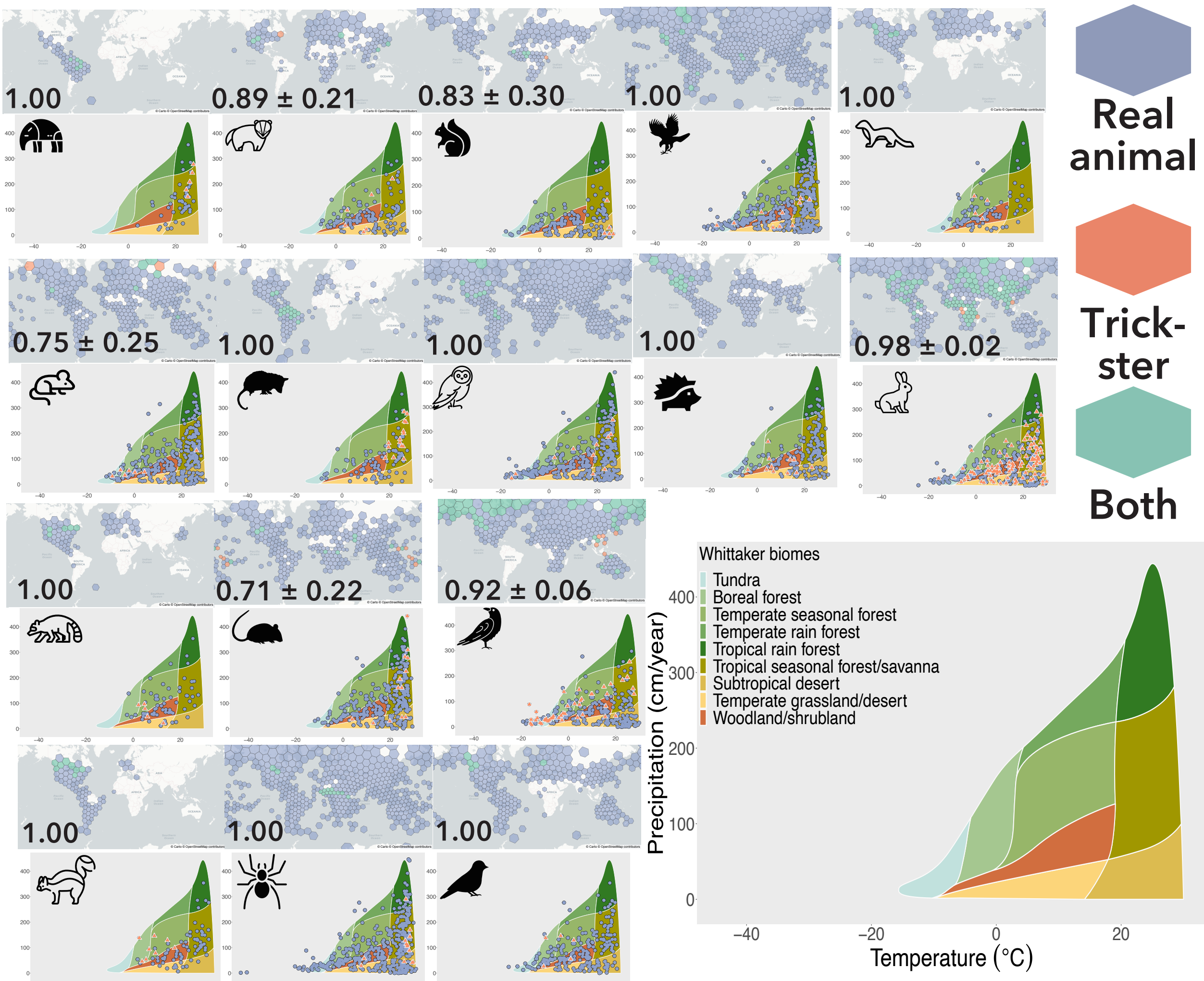

Figure 2: Distribution of tricksters and corresponding real animals

The distributions of 16 trickster animals (shown by icons) and corresponding real animals are shown on the world map (top) and Whittaker's biome (bottom), respectively. On the world map, the blue, orange, and green hex grids represent where only the real animals, only the tricksters, or both of them are reported, respectively. The left bottom numbers indicate the conditional probabilities that the corresponding real animals exist when the trickster animals are reported (i.e., the number of green grids over the number of red or green ones) and their 95% confidence intervals. In Whittaker's biome, the blue circles and the orange rectangles show the climate conditions where the corresponding real animals and tricksters are reported, respectively. The background colors represent the classes of the biomes (see the bottom right panel).

2). In the next subsection, we continue analyzing the constraints on the tricksters' distributions.

Table 1: Chi-squared test used to compare the frequencies of the biome classes

Category	Real animal vs Null	Trickster vs Null	Real animal vs Trickster
Anteater	1.46×10^{-4} ✓	5.00×10^{-1}	8.26×10^{-1}
Badger	2.13×10^{-5} ✓	1.02×10^{-1}	5.47×10^{-1}
Ground squirrel	2.09×10^{-7} ✓	5.00×10^{-1}	2.13×10^{-1}
Hawk	9.96×10^{-1}	6.29×10^{-1}	7.55×10^{-1}
Mink	2.59×10^{-9} ✓	4.08×10^{-2} ✓	5.72×10^{-1}
Mouse	1.77×10^{-2} ✓	7.11×10^{-2}	9.78×10^{-4} ✓
Opossum	1.07×10^{-2} ✓	4.08×10^{-2} ✓	1.80×10^{-1}
Owl	9.96×10^{-1}	8.47×10^{-1}	7.55×10^{-1}
Porcupine	3.38×10^{-2} ✓	2.45×10^{-1}	2.18×10^{-1}
Rabbit/Hare	8.00×10^{-2}	7.99×10^{-2}	2.92×10^{-1}
Raccoon	3.56×10^{-7} ✓	3.45×10^{-1}	7.69×10^{-1}
Rat	2.99×10^{-4} ✓	5.00×10^{-1}	5.47×10^{-1}
Raven/Crow	2.49×10^{-8} ✓	1.55×10^{-7}✓	1.81×10^{-5} ✓
Skunk	6.45×10^{-3} ✓	4.08×10^{-2} ✓	4.51×10^{-4} ✓
Spider	9.96×10^{-1}	6.29×10^{-1}	7.55×10^{-1}
Wren	8.84×10^{-7} ✓	3.40×10^{-1}	5.44×10^{-1}

✓represents p-value after FDR correction < 0.05.

Ecological constraints on animal tricksters

We next determined whether the trickster animals were freely distributed worldwide or restricted by their corresponding real animals. To address this, we calculated the conditional probability that a corresponding real animal existed in the local area where the trickster animal appeared in the local folklore. The values in Fig. 2 show the conditional probabilities of most (14 of the 16) animals were greater than 80%. These results suggest that the presence of real animals is a necessary condition for the presence of trickster animals. As the real animal distributions were restricted by the two climate conditions, we concluded that these conditions indirectly restricted the tricksters' distribution. However, further constraints other than these two climate conditions were unclear because only three trickster animals differed in the fractions of the biome classes from their corresponding animals (the right column of Table 1).

The mice and the rats show exceptionally lower conditional probabilities than the other animals. These species were, however, reported in the neighborhoods where they were consideredtricksters but the corresponding real animals were missing (i.e., the orange areas are surrounded by blue or green areas on the world maps of Fig. 2). The results suggest that the real mice and rats may not be absent t but the data were missing.

Neighborhood's effect on tricksters

Next, we investigated whether the presence of trickster animals waas affected by tricksters in the neighborhoods. This is because Fig. 2 shows the clusters of tricksters' distribution on the world map. We hypothesized that tricksters of a focal population were positively affected by the neighborhoods' tricksters. If this occured, we can expect that the trickster distributions are denser than when the tricksters randomly distribute in the locations of the corresponding real animals. The permutation test shows that in 13 of the 16 animals (animal and p-value: anteater $p = 9.58 \times 10^{-3}$; badger $p = 7.74 \times 10^{-1}$; ground squirrel 8.20×10^{-3}; hawk $p = 6.12 \times 10^{-1}$;

mink $p = 1.45 \times 10^{-2}$; mouse $p = 7.06 \times 10^{-3}$; opossum $p = 9.85 \times 10^{-11}$; owl $p = 1.23 \times 10^{-4}$; porcupine $p = 1.72 \times 10^{-21}$; rabbit/hare $p = 1.03 \times 10^{-6}$; raccoon $p = 3.69 \times 10^{-2}$; rat $p = 4.99 \times 10^{-1}$; raven/crow $p = 4.42 \times 10^{-10}$; skunk $p = 1.28 \times 10^{-4}$; spider $p = 6.50 \times 10^{-59}$; wren $p = 1.23 \times 10^{-4}$) the distance between the grids where the trickster animals existed was shorter than the distance between randomly chosen grids where the corresponding real animals existed.

Discussion

This study demonstrates that the distribution patterns of trickster animals are restricted by corresponding real animals and climate conditions. In other words, environmental factors can affect animal distribution in folklore. We focused solely on trickster animals that exist in the real world; however, our framework and approach can be applied to other animal motifs or cultures. For example, if our approach is applied to totem animals or supernatural creatures, it could deepen understanding of cultural or social identities such as magico-religious beliefs. Studies regarding nature's effect on human cultures can deepen our understanding of nature's contributions to people (Díaz et al., 2019). Our results, therefore, emphasize the importance of interdisciplinary research on human cultures from the perspectives of ecology and human science.

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Data availability

The original data on folklore is available from Dr. Yuri Berezkin. The codes used in this manuscript is available from https://github.com/ShotaSHIBASAKI/DistributionTrickSter.

Author contributions

S.S., R.N., and Y.N. conceived the research, S.S., R.N., and Y.N. compiled data, S.S. performed the statistical analysis, and S.S. wrote the first draft. All authors revised the manuscript and approved the final draft for publication.

Conflict of interest

The authors declare no conflict of interest.

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SI 1 Definitions of folklore, motif, and trickster

In this section, we provide a detailed discussion of folklore and tricksters as a motif. Although the term "folklore" can include material cultures (material culture; (Brown, 1998)), the term is commonly used to refer to oral traditions . Bascom (1965) defined folklore as prose narratives, which include three categories: folktales, legends, and myths. In the present study, we use an operational definition of 'folklore' as any records found in 'The Thematic Classification and Areal Distribution of Folklore-Mythological Catalogue', the lifetime work of Dr. Yuri Berezkin (Berezkin, 2015, 2022).

The catalog includes more than 3000 motif indexes developed by Berezkin, where motifs are defined as "*any episodes or images retold or described in narratives that are registered in at least in two (although normally in many more) different traditions*"(Berezkin, 2015, p. 37). Those motifs are classified into 13 major categories labeled with letters from A to N. Among those major categories, motifs that include 'trickster' is categorized under "M: ПРИКЛЮЧЕНИЯ III: ПРОДЕЛКИ И ЭПИЗОДЫ (M. Adventures III: Mischief and Episodes; translated by authors; see https://www.ruthenia.ru/folklore/berezkin/)".

Tricksters are a type of story character who conduct tricks or mischievous behaviors (e.g., stealing, cheating); and, their role is often understood metaphorically, such as 'a boundary-crosser' who travels or connects two different worlds (Hyde, 2008). Berezkin (2010) defined the character as "*any personage who deceives others, acts in a strange way or gets into comical situations but as one who combines two pairs of opposite characteristics which in the norm are related to different types of actors*" (p. 124). Further, Berezkin (2014) suggested animal or zoomorphic tricksters are found worldwide and have more stable characteristics; we consider that these features are also preferable to the objective of the present study.

SI 2 Extended Methods

SI 2.1 Data collection

We used folklore from the database constructed by Dr. Yuri Berezkin (Berezkin, 2022) via personal communication. Michalopoulos and Xue (2021) can also be consulted for further description of this database. We downloaded the data from the database in July 2022. We used the motifs of "Trickster–X" [m29a – m29i] and "Trickster is a X" [m29l –m29y] (an item in each square bracket [ ] shows Berezkin's motif index), where X represents the following common names of animals: anteater [m29qq], badger [m29x1], hawk [m29i], mink [m29d], mouse [m29n], opossum [m29l], owl [m29h], porcupine [m29r], rabbit/hare [m29g], raccoon [m29q], rat [m29m], raven/crow [m29a], skunk [m29c], spider [m29p], and wren[m29y]. We removed the motifs of (i) monkeys [m29o], (ii) water birds [m29j], (iii) foxes, coyotes, or jackals [m29b], (iv) feline (jaguar, ocelot, puma) [m29w], (v) small ungulate [m29v], and (vi) turtle, toad, frog [m29k] from our analysis because these motifs include diverse animals. The number of trickster data for each animal ranges from 6 to 190.

To each trickster animal, we assigned the scientific name of the corresponding animals using Wikipedia (Supporting dataset). The distributions of the real animals were collected from Global Biodiversity Information

Facility (GBIF) using occ_download function in rgbif library version 3.7.3 (Chamberlain et al., 2022) of R (version 4.2.1). These coordinate data were cleaned by CoordinateCleaner library (Zizka et al., 2019) using clean_coordinates function with tests of capitals, centroids, gbif, institutions, and zeros. After data cleaning, the number of data of each animal category varies from 4853 to 50898205.

Because the intensity of data collection of tricksters and real animals is likely to differ across species and locations, we converted the coordinates data into hex grid indices using geo_to_h3 function in h3 package version 3.7.4 (Uber Technologies Inc., 2018) of Python 3 (version 3.8.13). We set the resolution of the hex grids = 1, which generated about 840 grids across the world map. In addition, we did not consider the number of reports per grid: we used only the presence of tricksters and real animals data in each grid. After the conversion of the data, we obtained 257 tricksters' data and 3413 corresponding real animals' data.

Once the coordinates of tricksters and real animals had been converted, the climate data was assigned to each hex grid. We retrieved the annual mean temperature and annual precipitation of the center point of each grid from WorldClim 2.1 (Fick and Hijmans, 2017) using latlon-utils packages version 0.07 (Sommer, 2022) in Python 3. We chose the data from these two climate conditions because they classify the environments into 9 (+1 as an outlier) classes of Whittaker's biome (Whittaker, 1970). If the annual mean temperature and/or annual precipitation were not available (e.g., when a center point of a grid exists on an ocean), we estimated the two environmental data from the means at the coordinates where real animals were reported inside the grid. Classification into the biome classes was performed using platbiomes library (Stefan, 2018) in R.

SI 2.2 Statistical analysis

We investigated the fractions of Whittaker's biome classes. In each animal category, we compared the fractions of the biome classes between the tricksters and corresponding real animals. We also compared the fractions with a null model which was generated by the hex grids and corresponding environmental conditions where at least one of the real animals in our analysis was reported. This null model represents the fractions of the biome classes in the terrestrial areas. The comparison of the fractions of the biome classes was performed by the chi-squared test in R. The obtained p-values were corrected by the false discovery rate (FDR) method with p.adjust function.

We then investigated whether the presence of tricksters in each grid is restricted by the presence of corresponding real animals. We calculated the conditional probabilities that the corresponding real animals are reported in a grid where the focal animals appear as tricksters in the folklore.

Next, we determined whether the distribution of each trickster animal was clogged or not. Since the above analysis suggests that the presence of the corresponding real animals is necessary for the presence of a trickster (Fig. 2), the null hypothesis is that a focal animal appears as a trickster where the corresponding real animals are observed. We compared the median distance between the hex grids where the focal animals are reported as tricksters and the median of the simulated distances under the null hypothesis. We generated the simulated distributions of tricksters under the null hypothesis by randomly selecting as many hex grids that the corresponding real animals exist as the number of grids that the focal tricksters were reported. By generating 5000 such distributions in each animal, we obtained the probability distributions of the median distances under the null hypothesis, which enabled us to calculate the p-values. The obtained p-values were corrected by FDR method using multitest.fdrcorrection function in statsmodels library (Seabold and Perktold, 2010) in Python 3.

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