

Numic Fires: Modeling the Effects of Anthropogenic Fire on Foraging Decisions in the Great Basin

Kenneth B. Vernon, Kate E. Magargal, Ashley K. Parker, Will Rath & Brian F. Coddling

Department of Anthropology & Archaeological Center, University of Utah

Introduction

Across Western North America, hunter-gatherers modified their surrounding environment with the application of fire (1; 11; 15). However, to date we lack a general theoretical framework to investigate the reasons why people would burn or its effects on traditional foraging economies. To begin to fill in these gaps, here we examine the immediate benefits fire may provide in the context of driving rabbits in shrubland ecosystems across the ethnographic Great Basin occupied by Numic speaking foragers.

The Model: Band-Level Diet Breadth

We approach this problem with a spatially explicit hierarchical model of optimal diet breadth based on the prey choice model from Charnov (5). The basic model asks whether a forager should pursue a resource on encounter or continue searching for more profitable resources. For each resource i , the answer depends on the encounter rate with higher profitability resources. The overall in-patch return rate for any set of resources can be calculated as:

$$\frac{E_j}{T_j} = \frac{\sum \lambda_i e_i p_i}{1 + \sum \lambda_i h_i p_i} \quad (1)$$

patch prey/resource

Resources are added to the set in order of their post-encounter return rate (e/h). The optimal set maximizes the overall return rate (E/T) in the j th patch so that it is always higher than it would be with the addition of the next lower ranking resource. This calculates the average return rate an individual achieves by foraging optimally within the j th patch, which can then be aggregated to determine the average return rate within the k th foraging range as the average product of encounters with each patch type:

$$\frac{\bar{E}_k}{\bar{T}_k} = \left\langle \frac{E_j}{T_j} \lambda_j \right\rangle \quad (2)$$

range patch

where

E the average energy acquired from the j th patch or k th range

T the average time spent in search and handling within the j th patch or k th range

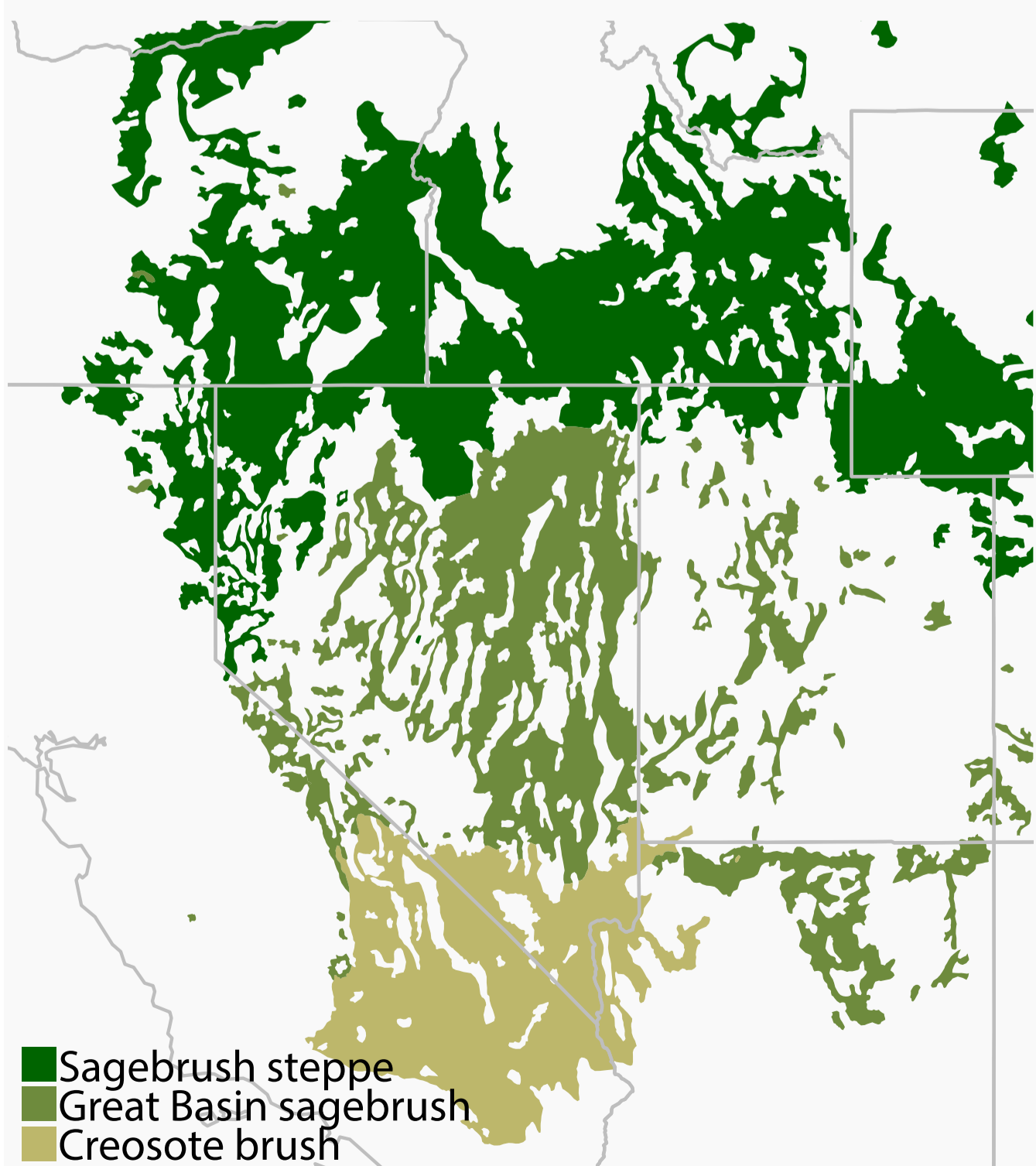
λ the encounter rate with the i th resource or j th patch

e_i the total expected amount of energy acquired by handling the i th item

h_i the total expected time spent handling (pursuit and processing) the i th item

p_i the probability that a forager will take the i th item on encounter

Methods: Resources, Patches and Ranges



We implement this approach by combining in-patch foraging data from Simms (13) to determine the optimal diet breadth, vegetation data from Küchler (10) to estimate patch encounter rates within each foraging range, and band-level boundaries from Stewart (16), Stewart (14), Kelly (8), Kroeber (9) and others to estimate the distribution of foraging ranges.

Figure 1. Potential natural climax vegetation from Küchler (10) represents major shrubland habitats across the Great Basin within which ethnographic groups may have driven rabbits with fire (6).

Results: Shrubland Diet Breadth

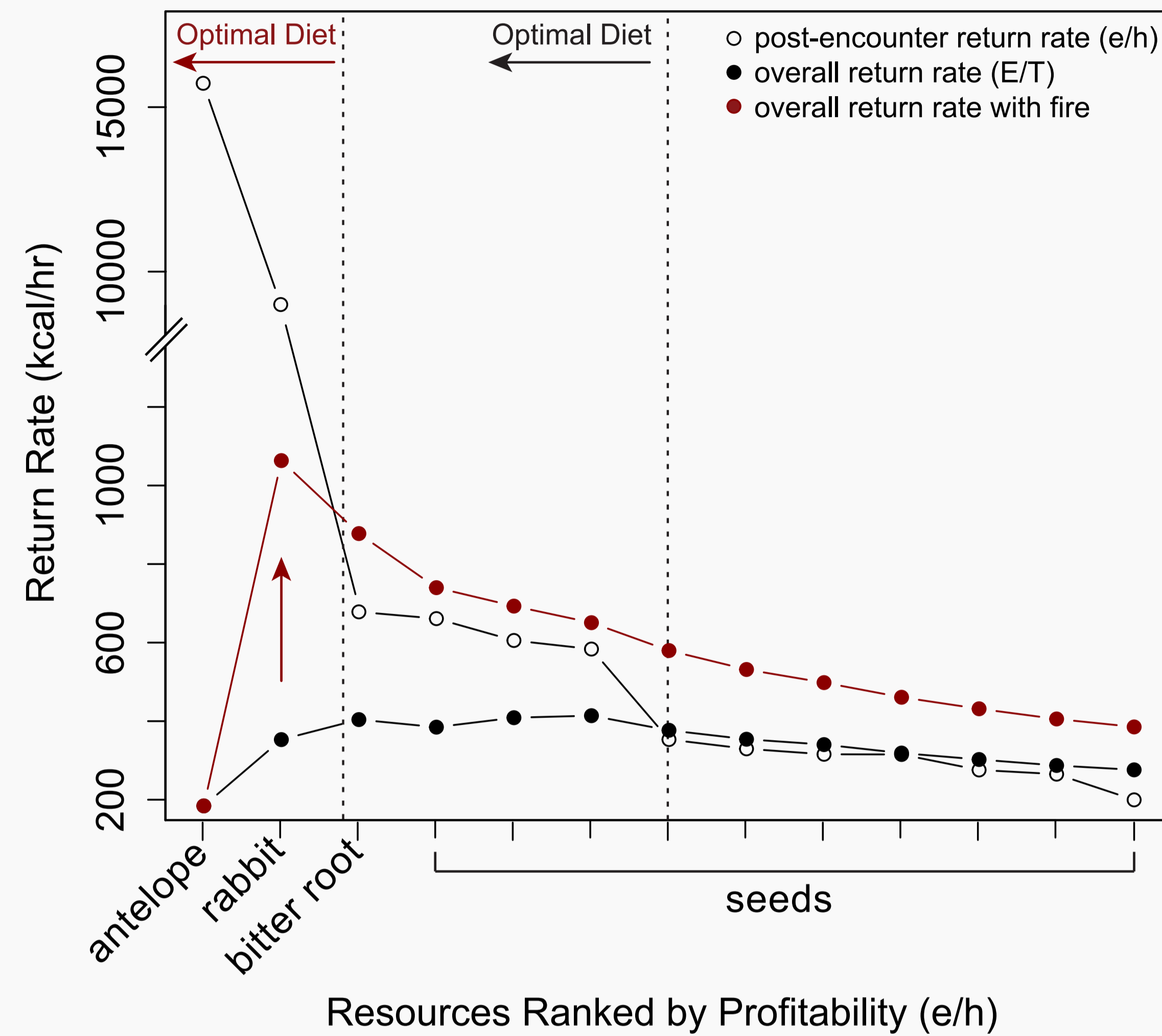


Figure 2. Results of in-patch resource choice model comparing dietary selectivity with (red) and without (black) the use of fire for driving rabbits.^b Using fire to drive rabbits increases the encounter rate to a point where all plant resources are excluded from the optimal diet, increasing the overall return rate by over 60%.^c While this strategy would only occur about once per year (6), it would have provided an immediate benefit to foragers and may have resulted in significant long-term environmental change (11).

Results: Band-Level Return Rates

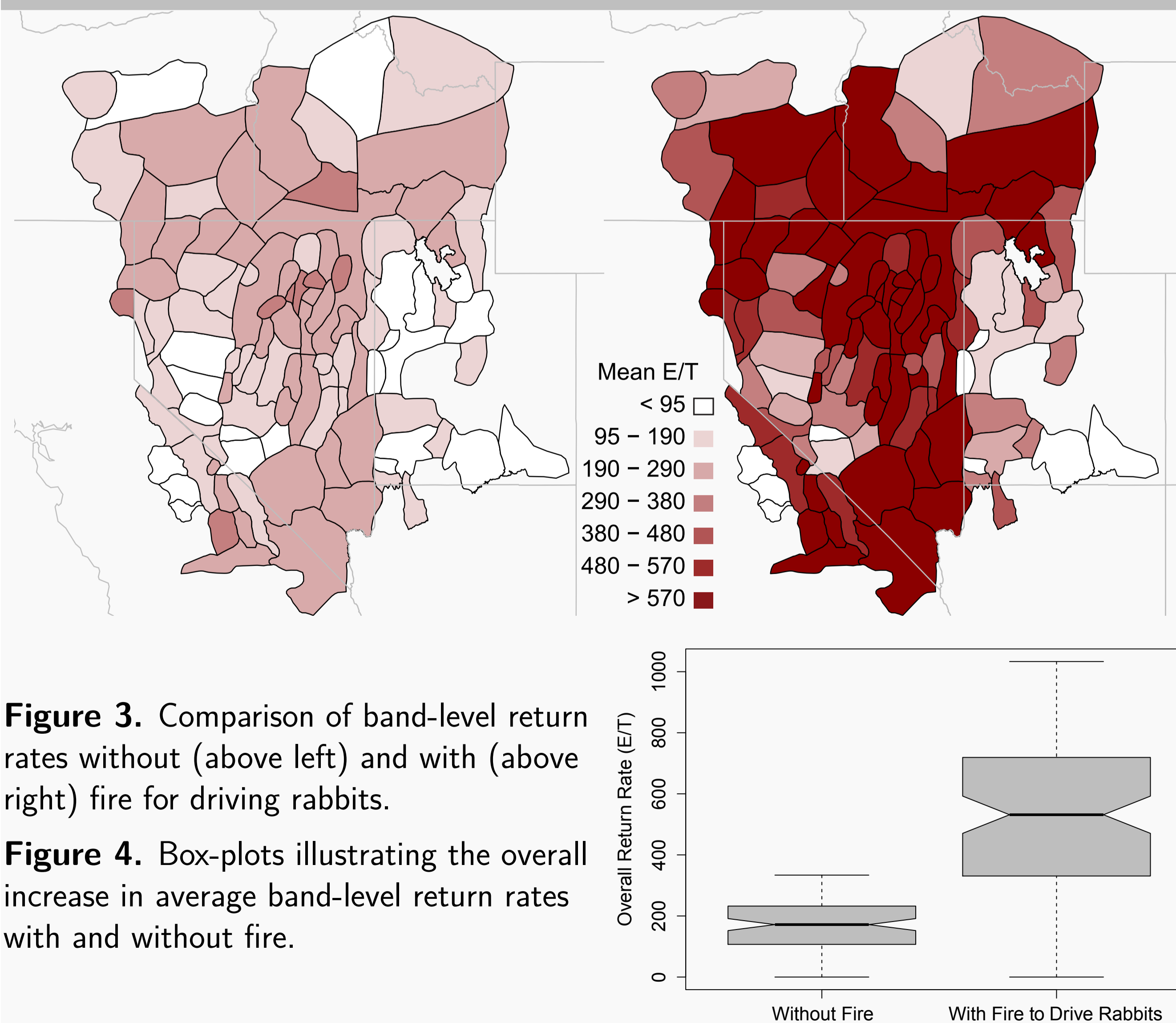
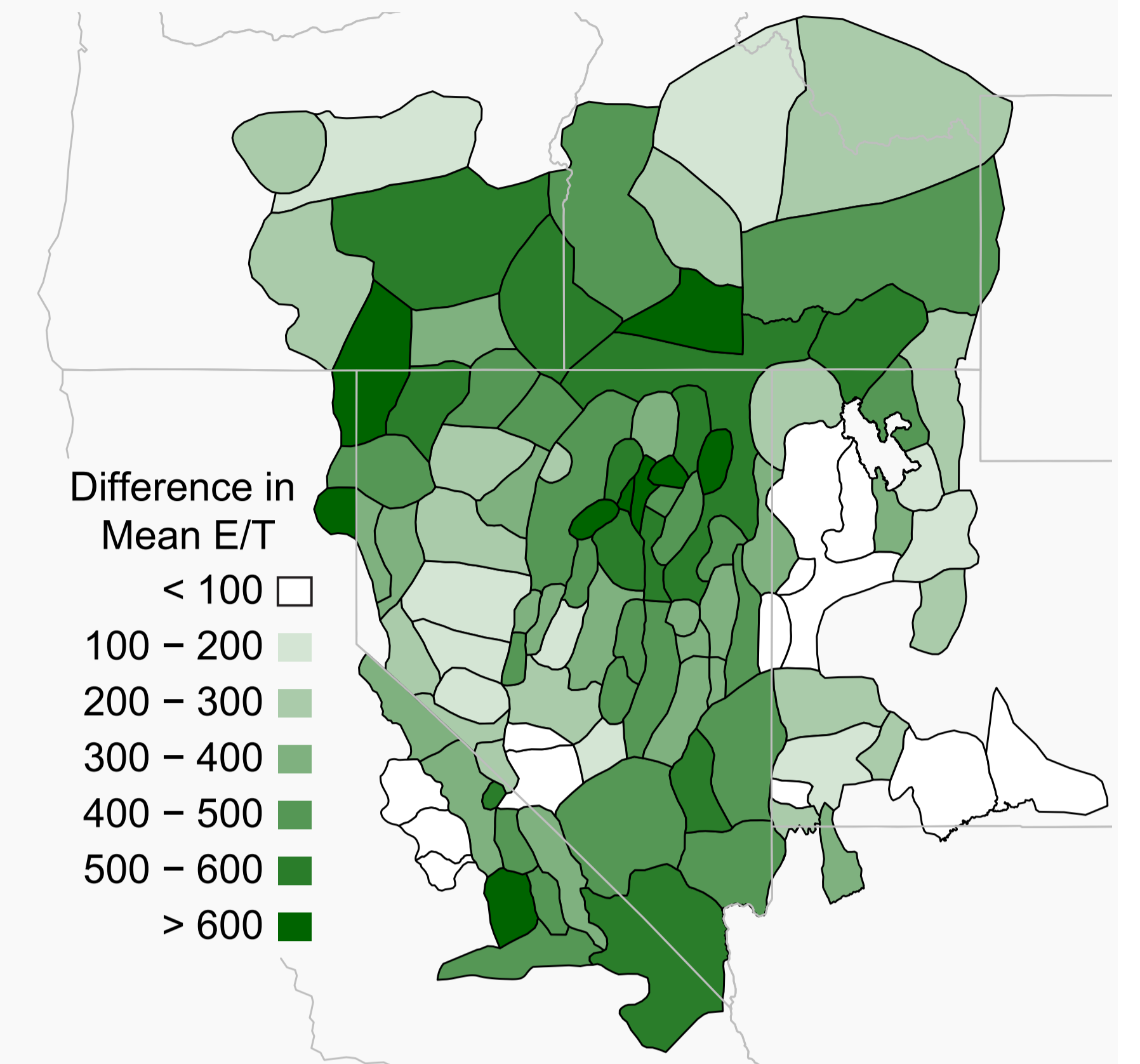


Figure 3. Comparison of band-level return rates without (above left) and with (above right) fire for driving rabbits.

Figure 4. Box-plots illustrating the overall increase in average band-level return rates with and without fire.

Results: Difference with Fire

Figure 5. Difference between the average in-patch return rates (eq. 2) for each band (E_k/T_k) with and without the use of fire to drive rabbits. The results indicate that fire significantly increases foraging returns across most of the Great Basin where shrubland habitat is present (cf. Figure 1), but is greater among some bands than others.



Conclusion

These preliminary results suggest fire may have had a significant impact on hunter-gatherer economies across the Great Basin, even in the case where fire was only used once a year for driving rabbits. This impact would have varied based on the structure of vegetation, causing foragers occupying different band territories to receive differential benefits from application of fire. This variation across the Great Basin has implications for archaeological questions, such as the timing and order of population expansion. Explaining these human-fire-vegetation dynamics is also important for land managers working towards improved systems of wildland fire management. Coupled with this synthesis of Numic bands distributions across the Great Basin, our project will continue to integrate ethnographic and environmental data on broad spatial scales to tackle theoretical and empirical research questions in intermountain human ecology.

Footnotes

^a Animal encounter rates were reduced by the probability that pursuit resulted in failure. ^b This is a low estimate for rabbit drive encounters. ^c All analyses were run in the R environment (12) using spatial libraries (2; 3; 4). ^d This work is part of an ongoing interdisciplinary research project examining human-fire dynamics across the Great Basin. Thanks to Doug Bird, Joan Coltrain, Jim O'Connell, Chris Parker for advice and guidance, and to Steve Simms and David Zeanah for providing the foundations for this work. Support for this research comes from the University of Utah Research Foundation and the Global Change and Sustainability Center.

References

- [1] Anderson, M.K. *Tending the Wild*. University of California Press, Berkeley, 2005.
- [2] Bivand, R. et al. Bindings for the geospatial data abstraction library, 2014. <http://www.gdal.org>.
- [3] Bivand, R. et al. *Maptools: Tools for reading and handling spatial objects*, 2014.
- [4] Brunsdon, C. and H. Chen. *GIStools: Some further GIS capabilities for R*, 2014. <http://cran.r-project.org>.
- [5] Charnov, E.L. Optimal Foraging: Attack Strategy of a Mantid. *The American Naturalist*, 110:141-151, 1976.
- [6] Fowler, C. S. Historical perspectives on Timbisha Shoshone land management practices Death Valley California. In Reitz et al. (eds), *Case Studies in Environmental Archaeology*, Interdisciplinary Contributions to Archaeology, pp. 43-57. Springer, 2008.
- [7] Griffin, D. Prehistoric human impacts on fire regimes and vegetation in the Northern Intermountain West. In Thomas R. Vale, editor, *Fire, Native Peoples, and the Natural Landscape*, pages 77-100. Island Press, Washington D.C., 2002.
- [8] Kelly, I.T. Southern Paiute bands. *American Anthropologist*, 36:548-560, 1932.
- [9] Kroeber, A.L. *Handbook of the Indians of California*. Smithsonian Institution, Bureau of American Ethnology, 1925.
- [10] Kuchler, A. *Potential Natural Vegetation of the Conterminous United States*, 1964. Special Publication No. 36. Digital version uploaded and reviewed by the Conservation Biology Institute: <http://databasin.org/people/consbio>.
- [11] McAdoo, et al. Aboriginal precedent for active management of sagebrush-perennial grass communities in the Great Basin. *Rangeland Ecology and Management*, 66:241-253, 2013.
- [12] R Development Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation, Vienna, Austria, 2014. v. 3.1.0
- [13] Simms, S. R. *Behavioral Ecology and Hunter-Gatherer Foraging: An Example from the Great Basin*. Number 381. British Archaeological Reports, International Series, 1987.
- [14] Stewart, J.H. *Basin-Plateau Aboriginal Sociopolitical Groups*. Bureau of American Ethnology, Washington DC, 1938. Bulletin 120.
- [15] Stewart, O.C. The effects of burning of grasslands and forests by aborigines the world over. In Henry T. Lewis and M. Kat Anderson, editors, *Forgotten Fires: Native Americans and the Transient Wilderness*, pages 67-338. University of Oklahoma Press, Norman, 2002.
- [16] Stewart, O.C. The Northern Paiute bands. *University of California Anthropological Records*, 2(3):127-149, 1938.
- [17] Zeanah, D. W. Sexual division of labor and central place foraging: a model for the Carson Desert of Western Nevada. *Journal of Anthropological Archaeology*, 23:1-32, 2004.