

# Testing the Enemy Release Hypothesis in Ungulates (Artiodactyl and Perissodactyl) and Carnivores

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## Introduction

The Enemy Release Hypothesis is that greater success of invasive species than native species is due to lack of control by pathogens, parasites, and predators (Colautti et al. 2004).

A few reasons for greater success:

- (1) Specialist enemies of the invasive species may be absent in the new invasive region
- (2) Host switching of native specialist enemies to an invasive host is unlikely
- (3) Generalist enemies that are already present will have a greater impact on the native competitors

The competing species are attacked by their own specialist enemies, and all the hosts (native and invasive) are attacked by generalist enemies.

(Keane and Crawley 2002)

## Objective:

The goal of this project is to determine whether individuals in mammal populations of a given species outside of their native range are generally infected by fewer parasites than those from populations within the native range.

## Host Parasite Richness Methods

The data for this following analysis is derived from the *Global Mammal Parasite Database version 2.0* (Stephens et al. 2017)

We compiled a database for our analysis entirely from sub-setting entries in the GMPD2.0.

- We investigated 39 species in the GMPD database with entries from both inside and outside of their native range.
- For these species we calculated the Parasite Species Richness value inside their native range (Native PSR), and a separate Parasite Species Richness Values outside of their native range (Invasive PSR).
- To account for variation in sampling effort, we also included the citation count and number of animals sampled for each species for both the native and invasive sets of entries.

	p-value	rho
(Native) Citation count vs. PSR	2.83E-14	0.9315844
(Invasive) Citation count vs. PSR	1.44E-15	0.9445953
(Native) Individuals count vs. PSR	7.69E-07	0.7584191
(Invasive) Individuals count vs. PSR	1.22E-07	0.7904844
(Native) Citation count vs. Individuals count	4.73E-09	0.8361585
(Invasive) Citation count vs. Individuals count	6.69E-09	0.831846

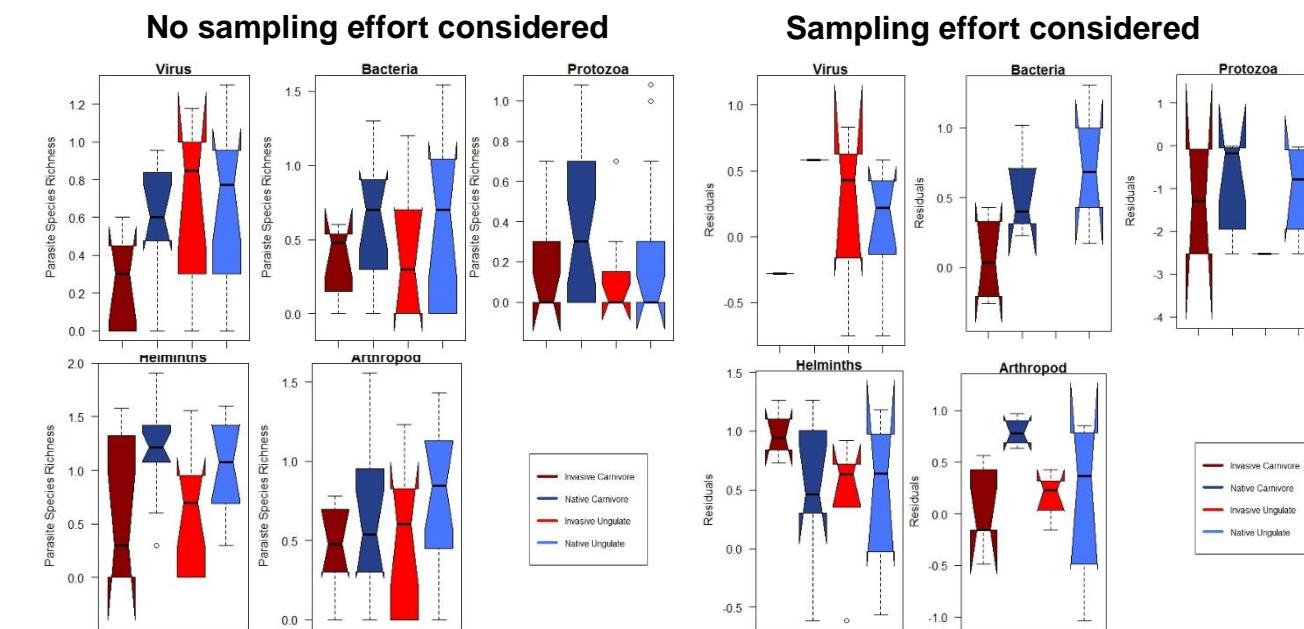
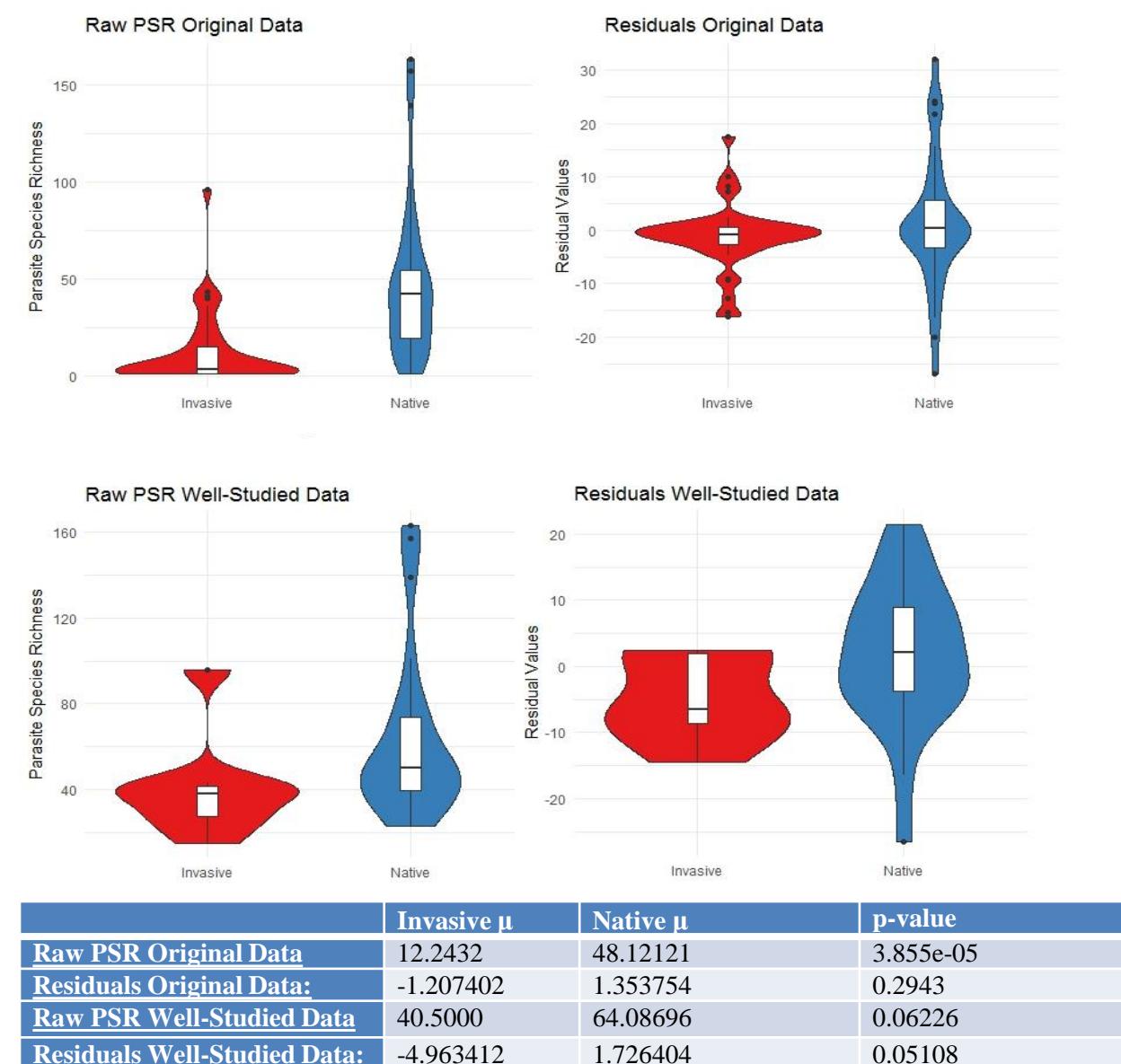
We used a Generalized Additive Model (GAM) of PSR and sampling effort to get the residual values of PSR. Because of the strong correlation between our measures of sampling effort we compared AIC scores of models using citation count, host count, or both as predictors of PSR to avoid overfitting. We then used the model with the lowest AIC to generate residuals of PSR. These residual values were used to accurately test Parasite Species Richness against the different ranges (Native vs. Invasive).

Many of the entries in our data had very few citations listed (i.e., their parasite diversity was poorly sampled). This was potentially adding noise to our analyses. To focus on the more heavily studied host species we removed all entries in our data with less than 15 citations\* listed and repeated our analysis.

\*This still left us with over half of our data.

To further investigate our results we depicted patterns of PSR by host group (either ungulate or carnivore) and parasite type (virus, bacteria, protozoa, helminths, or arthropods).

## Host Parasite Richness Results



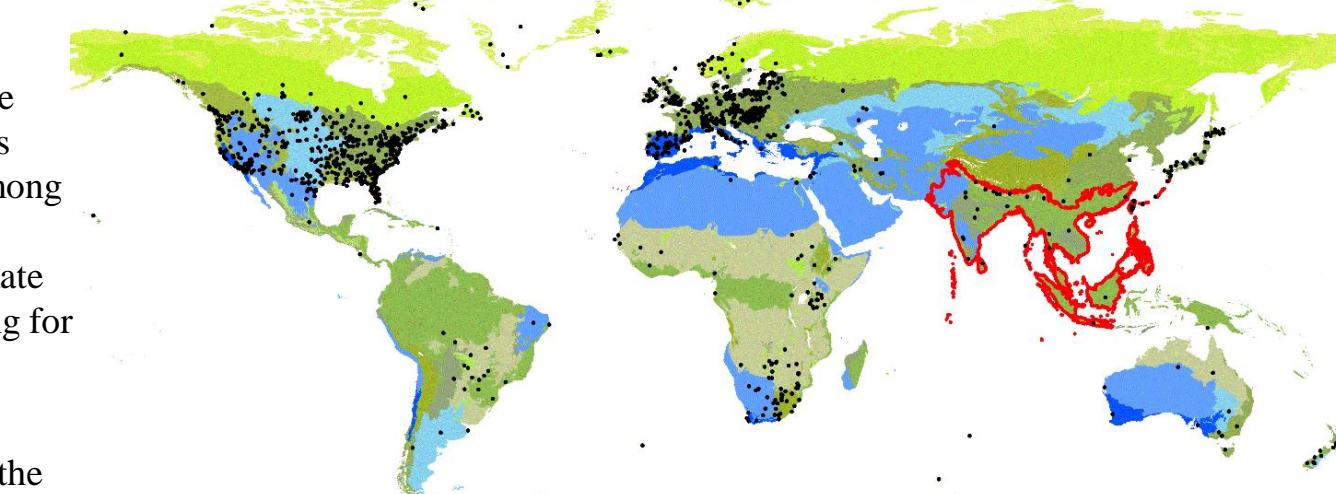
## Conclusion

- Analyses restricted to well-studied hosts showed a greater reduction in PSR in invasive ranges.
- Project results highlight the importance of considering sampling effort measures when calculating species richness.
- Excepting helminths, all parasite types showed lower species richness in the invasive range vs. native range of mammal hosts.

## References

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Colautti, Robert I., Anthony Ricciardi, Igor A. Grigorovich, and Hugh J. Macisaac. "Is invasion success explained by the enemy release hypothesis?" *Ecology Letters* 7.8 (2004): 721-33. Web.  
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## Spatial Patterns



Absolute Parasite Species Richness was analyzed among biogeographical regions and climate zones; controlling for sampling effort.

Blue regions on the map are climate zones with significantly higher PSR, while the outlined Indo-Malay biogeographic region had significantly lower PSR. Points show data locations.

	Biogeographical Region	Climate/Habitat Zone	Estimate	p-value
Biogeographical Region	Indo-Malay		-0.332	0.00836**
	Temperate Grasslands, Savannas and Shrublands		0.246	0.03191*
	Mangroves		0.268	0.01292*
	Tropical and Subtropical Dry Broadleaf Forests		0.240	0.03347*
	Tropical and Subtropical Moist Broadleaf Forests			
	Tropical and Subtropical Coniferous Forests			
	Tropical and Subtropical Grasslands, Savannas and Shrublands			
	Tundra			

The spatial data for the following analysis is from The Nature Conservancy's 'Terrestrial Ecoregions' GIS Data.

## Prevalence

Prevalence data from the GMPD was compared between identical host-parasite pairs where records existed inside and outside their native range. The average prevalence values were considered for analysis only if the same method of sampling (serology, necropsy, or PCR) was used between the invasive and native pairs. A t-test was run to compare the parasite prevalence means across either native or invasive ranges; the invasive and native mean values were almost identical.

p-value	Invasive $\mu$	Native $\mu$
0.4768	0.2664647	0.3095706

Based on these results, it seems that for parasites carried over into an invasive range similar average prevalence values are maintained to the average prevalence found in their native range.

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