GUT MICROBIOTA OF RING-TAILED LEMURS (*LEMUR CATTA*) VARY ACROSS NATURAL AND CAPTIVE POPULATIONS AND CORRELATE WITH ENVIRONMENTAL MICROBIOTA

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Abstract

Background, methods & predictions

Gut microbiomes play critical roles in maintaining host nutrition and overall health. It is well established that gut microbiomes differ between captive and wild conspecifics, a pattern largely attributed to distinct diets. Often, diets of animals under human care are understandably restricted and cannot recapitulate diets of wild animals. Another less well-studied aspect of diet is the ingestion of environmental microbes, or 'environmental acquisition'; animals ingest microbes via dietary items or exposure water or soil microbes (e.g., via geophagy). Whereas wild animals are exposed to natural habitats that are rich in environmental microbes, captive animals often inhabit settings with minimized or altered microbial environments (e.g., via indoor enclosures, cleaning regimens, sanitized/prepared diets). Here, we test for effects of diet and environmental acquisition in shaping the gut microbiomes of the ecologically flexible, ring-tailed lemur (*Lemur catta*), across wild and captive settings in Madagascar and the U.S.

We collected lemur fecal and soil samples from 13 populations of ring-tailed lemurs (n=209) representing a large portion of the lemurs' natural range in Madagascar and different captivity settings in Madagascar and the U.S. We used 16S rRNA sequencing to characterize lemur and soil microbiomes and statistical tools based on source-sink ecological theory to analyze covariation between the two microbial communities.

If diet shapes lemur gut communities, we expect captive lemurs in Madagascar and the U.S. to be most similar (reflecting commercial diets). If environmental acquisition shapes lemur gut microbiomes, we expect (a) wild lemurs to have greater proportions of soil-associated microbes in their guts, (b) wild and captive lemurs in Madagascar to share soil-associated microbes, differing most drastically from lemurs in the U.S., and (c) captive lemurs with access to outdoor enclosures to have greater proportions of soil-associated microbes compared to lemurs housed indoors.

Results

Despite the similar, commercial diets of captive lemurs on both continents, captive lemurs in Madagascar were more similar to their wild counterparts than to captive lemurs in the U.S., suggesting that non-dietary factors govern some of the variability. Soil microbes were similar across sites in Madagascar and were most distinct between Madagascar and U.S. In support of the role of environmental acquisition, soil-associated microbes were more prevalent in wild lemurs compared to captive lemurs and the acquired soil microbes were specific to the lemurs' environment. Within lemurs at the Duke Lemur Center (Durham, NC), those that free-ranged in outdoor, forested enclosures had significantly greater proportions of soil-associated microbes in their guts compared to lemurs that were housed indoors.

Conclusion

Perturbed microbiomes are increasingly recognized as culprits of obesity, gastrointestinal distress, and even associated mortality in captive animals. We suggest that environmental acquisition may be a component of 'bio-augmenting' captive animal gut microbiomes, a process by which gut microbes are reshaped to better promote host nutrition and health. Identifying what comprises healthy gut microbiomes is a complex, ongoing area of research; nonetheless, we show that exposure to environmental microbes is a potential driver of microbial communities and should be considered as a component of animal health.