LIFE ON THE EDGE: NEW TOOLS TO TRACK FOREST-LEMUR INTERACTIONS

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INTRODUCTION

- Monitoring the foraging and dietary habits of lemurs is essential to their conservation, giving insight into the effects of continuing anthropogenic disturbances on Madagascar.
- Lemurs are **essential to the maintenance and health of Malagasy forests**, dispersing the seeds of fruiting trees, enabling pollination, and providing fertiliser and nutrient cycling. Diets are the key to assessing these interactions in greater detail.
- **Therefore, complementary approaches are needed to fill the gaps in our understanding of lemur foraging habits and the interactions with their host forests. Is ORGANIC GEOCHEMISTRY the answer?**

PILOT SAMPLES from captive lemurs at Duke Lemur Center (DLC), NC, USA:
→3 lemur species (8 per species):

Propithecus coquereli	*Lemur catta*	*Varecia variegata*
Coquerel's sifaka	Ringtail lemur	Red ruffed lemur
FOLIVORE	GENERALIST	FRUGIVORE

→Equal representation of 2 habitat environments:

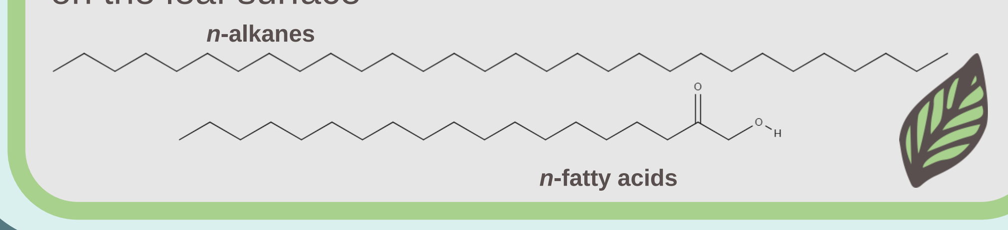
Natural Habitat Enclosures
Large, forested enclosures designed to replicate the wild environment, allowing foraging alongside provisioned diets.

Captive Enclosures
Smaller enclosures. Only available food is provisioned by the DLC.

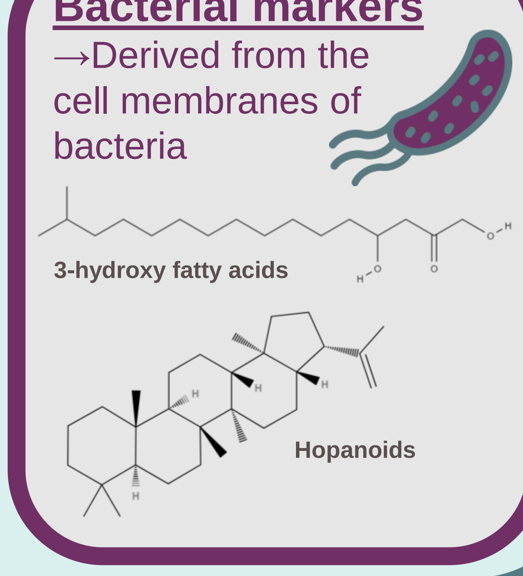
LIPID BIOMARKERS

- Biomarkers are molecules indicative of biological life, they can be linked to specific organisms and/or biological processes.
- The molecules are simple and preserved in geological sediments for millions of years without being broken down. Therefore, they will survive transport through the gastrointestinal tract of a lemur.

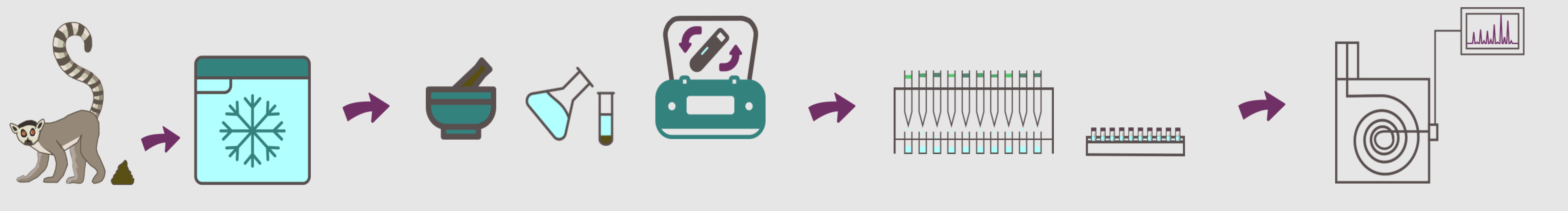
Leaf wax markers
→Produced by all higher plants, forming a waxy cuticle on the leaf surface



Bacterial markers
→Derived from the cell membranes of bacteria



METHODOLOGY: ORGANIC GEOCHEMISTRY



Faecal collection and sample freeze-drying → Sample grinding and **total lipid extraction** by organic solvents, centrifuge and ultrasonication → Separation by **column chromatography** → Analysis by **GC-MS** and **GC-FID**

ECOSYSTEM SERVICES FROM LEMURS

→ Seed dispersal of large fruiting trees:

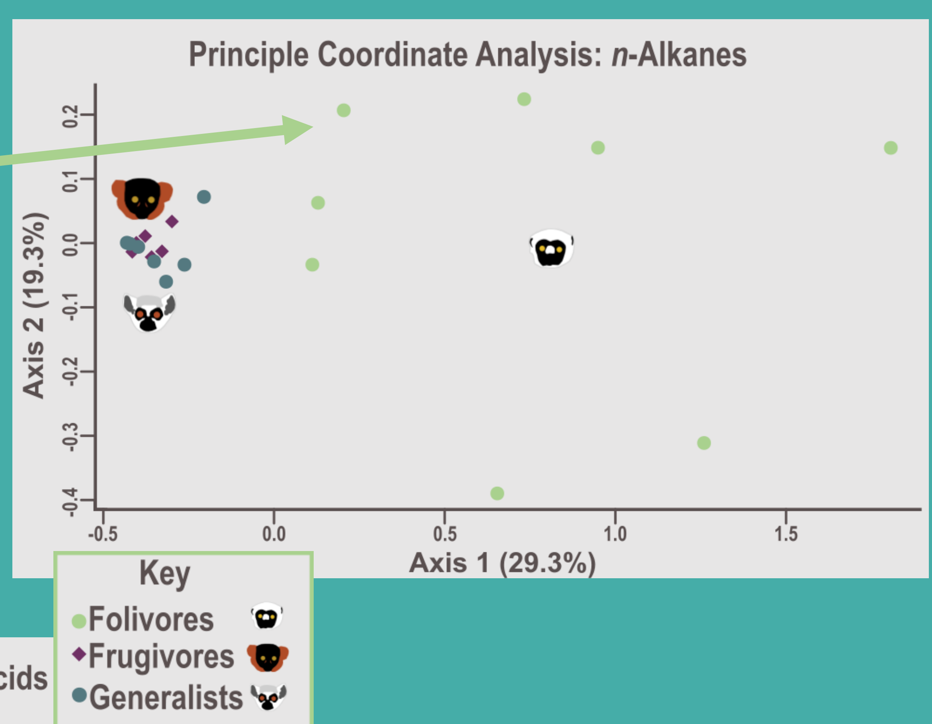
A selection of fruit seeds dispersed by two species of sympatric brown lemur over a two week observation period in a pristine forest.

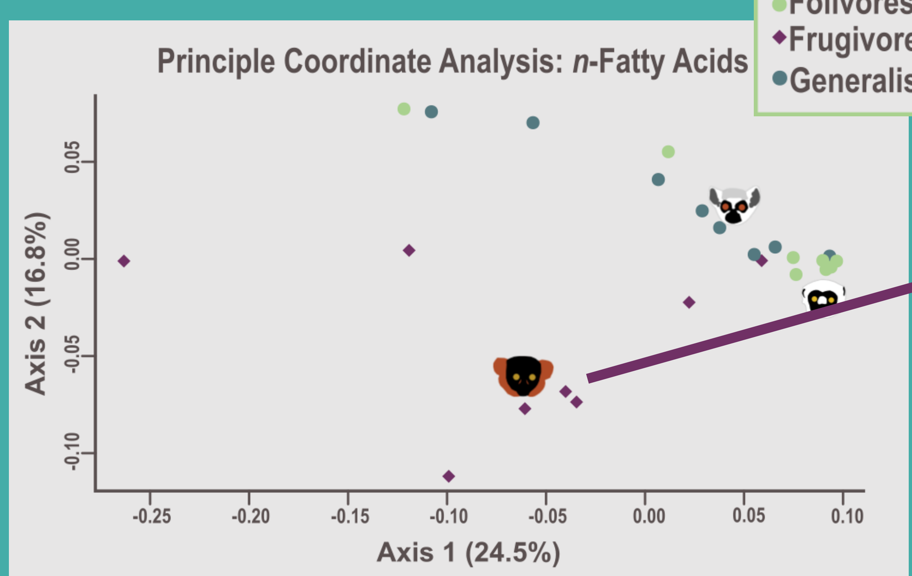
RESULTS

N-ALKANES

→Clear separation of the **folivores** based on faecal *n*-alkane signatures.

→Patterns from **frugivore** and **generalist** samples closely grouped (almost identical).





N-FATTY ACIDS

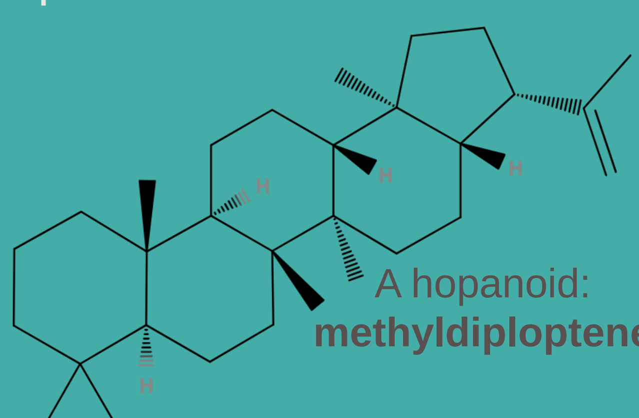
→Clear separation of the **frugivores** based on faecal *n*-fatty acid signatures.

→**Folivore** and **generalist** samples grouped, but quite spread out.

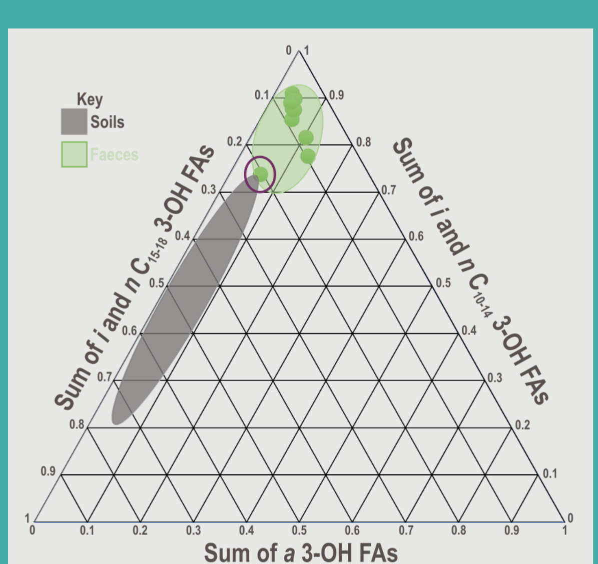
METHYLDIPLOPTENE

→Found in all **folivores**, and those **generalists** **without** Natural Habitat Enclosure access.

→Completely **absent** in the **frugivores**.



A hopanoid: **methyldiploptene**



3-HYDROXY FATTY ACIDS (3-OH FAS)

→**3-OH FA faecal signatures** show SOME overlap with **soil 3-OH FAs**.

→From paired behavioural data, individuals who were observed to consume ~5% of soil in the diet fall into the overlapping section.

DISCUSSION

- *n*-Alkanes appear to reliably distinguish the **PROPORTION OF LEAF MATTER** in the diet given their high concentration in leaf versus fruit cuticles.
- *n*-Fatty acids appear to reliably distinguish a **RELIANCE ON FRUIT MATTER** in the diet, given that they are in significantly higher concentrations in the cuticles of fruits than leaves.
- Bacterial hopanoids show great promise. The presence of methyldiploptene is **INDICATIVE OF ANAEROBIC METHANOTROPHS** in the gut microbiome. This could be a result of something they consume that is **more fibrous** than other dietary components: potentially dead wood, bark or pine cones etc., these are documented fallback foods in the wild.
- 3-OH FAs show promise as a way to identify **GEOPHAGY**. At present, the only known way to identify this habit is by observation. **Do they partake in geophagy to enrich their gut microbiomes?**

THEREFORE: organic geochemistry has a lot of promise to reconstruct dietary profiles. It is possible to distinguish feeding strategies, preferences, and individual variation. These can be monitored to alert us to changes we may not notice from observation, which will inform on their relationship with the forest.

FUTURE DIRECTIONS

→Expand dataset, including samples with paired direct dietary observation and DNA gut microbiome data, to further distil specific individual, seasonal/temporal, and habitat-specific dietary patterns from faecal biomarkers.

→ 3-OH FA analysis of soil from DLC to compare to faecal 3-OH FAs, as signatures are highly regional. The identified trend may become stronger.

→Compare faecal profiles to profiles of the original foodstuffs.

→Apply compound-specific stable isotope analysis to infer trophic position ($\delta^{15}N$), foraging patterns (δD) and crop raiding habits ($\delta^{13}C$).

→**EVENTUALLY**, apply and compare these datasets to wild populations.

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