Saturniid and sphingid moths as novel models for the study of insect diversity and macroecology

Liliana Ballesteros-Mejia
Postdoc researcher

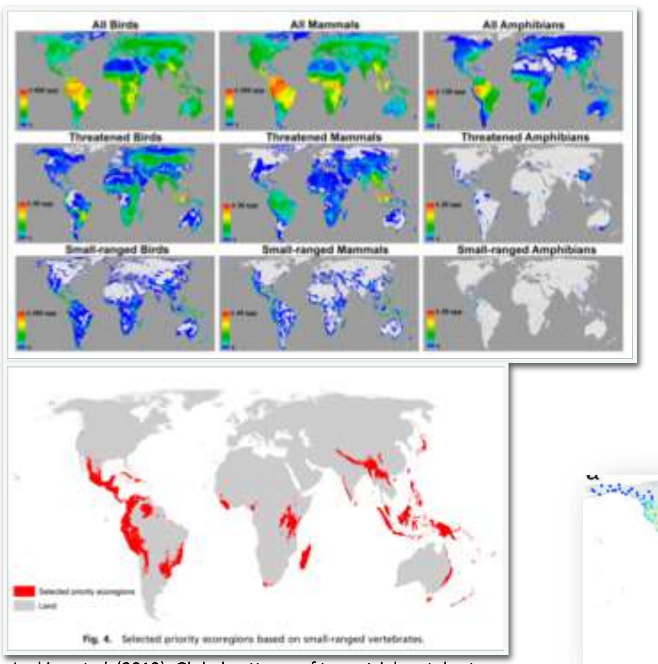
Saturniid and sphingid moths as novel models for the study of insect diversity and macroecology

PRESENTATION OUTLINE

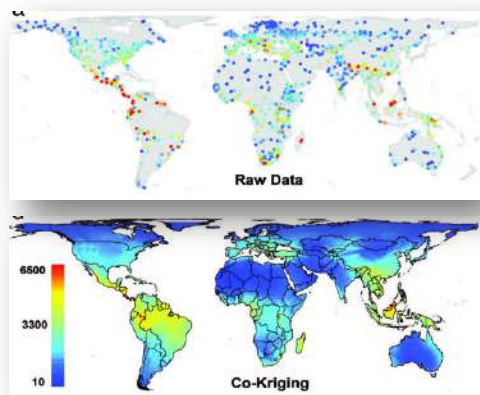
- **INTRODUCTION**
- SATURNIID & SPHINGID MOTHS AS NEW MODELS
- ADVANCES IN SYNTHESIS OF INFORMATION
- UNDERSTANDING PATTERNS
- TAKE HOME MESSAGE & PERSPECTIVES

INTRODUCTION

Conservation policies are largely derived from vertebrate and plant data



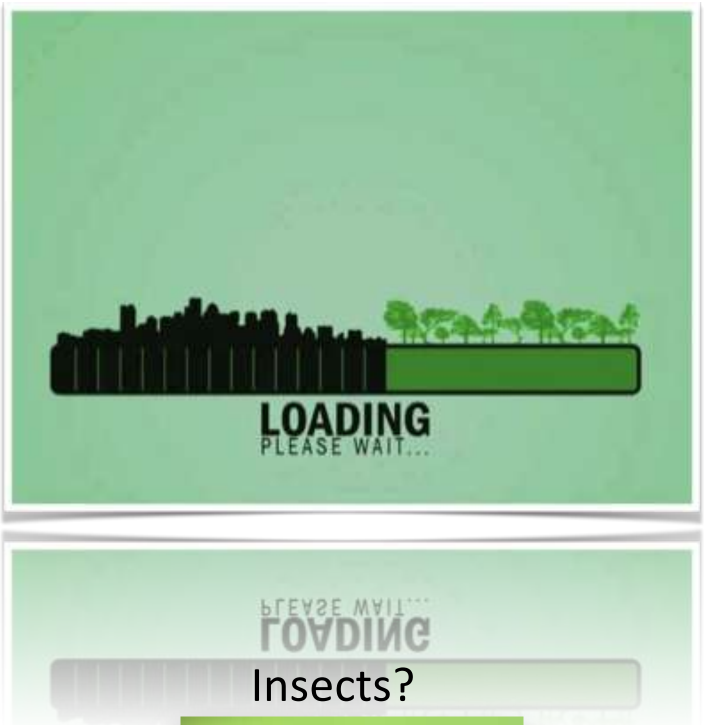
Jenkins *et al.* (2013). Global patterns of terrestrial vertebrate diversity and conservation. PNAS 110



Kreft & Jetz (2007). Global patterns and determinants of vasculat plant diversity. PNAS 104

Insects make up for ~ 50% of species worldwide and play important ecological role. Affected by climate change and habitat disturbance

INTRODUCTION



Insects?

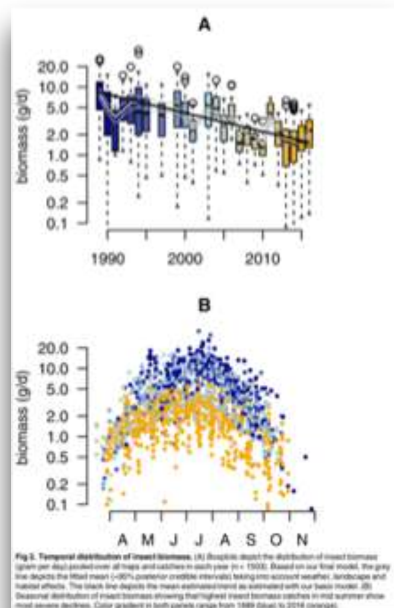
Loss of insects jeopardize ecosystem services.

RESEARCH ARTICLE

More than 75 percent decline over 27 years in total flying insect biomass in protected areas

Caspar A. Hallmann[1]*, Martin Sorg[2], Eelke Jongejans[1], Henk Siepel[1], Nick Hofland[1], Heinz Schwan[2], Werner Stenmans[2], Andreas Müller[2], Hubert Sumser[2], Thomas Hörren[2], Dave Goulson[3], Hans de Kroon[1]

Hallmann *et al.* (2017). PLoSOne e0185809



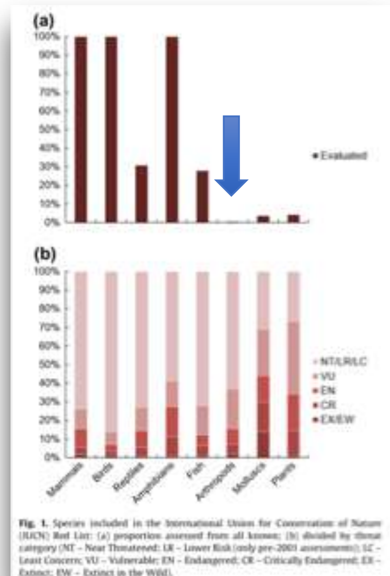
Insect biomass (gr/day)

Blue = 1989; Orange= 2016

Seasonal variation in Insect biomass

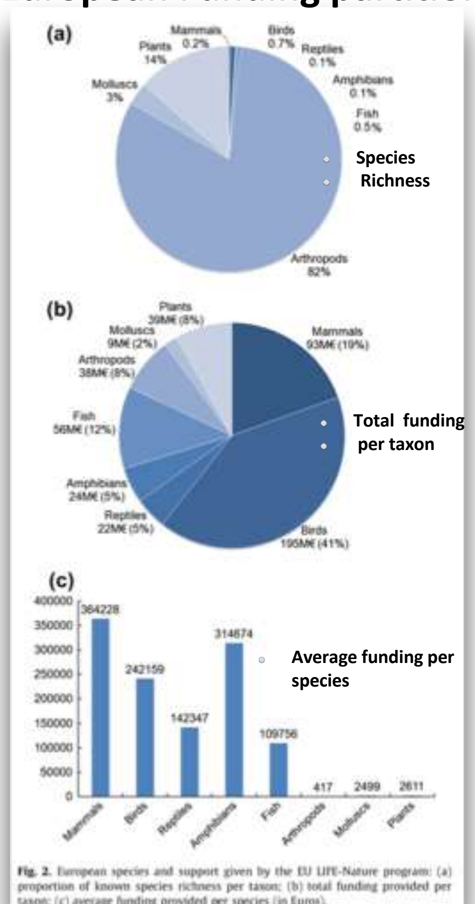
INTRODUCTION

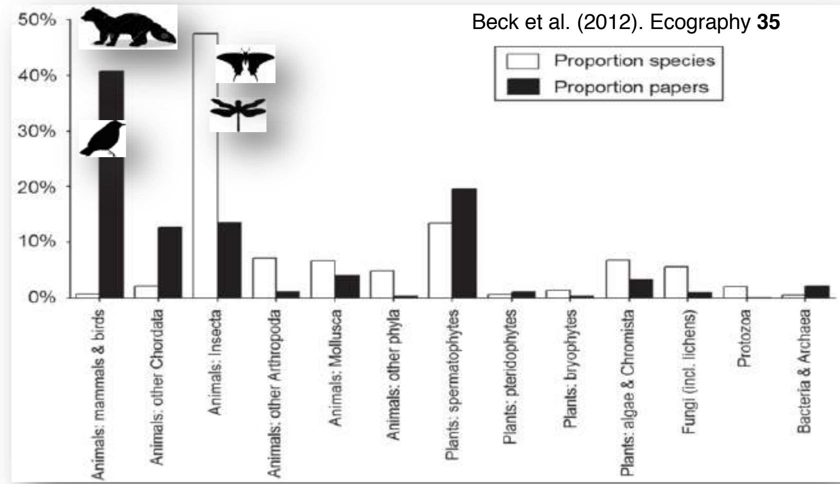
Knowledge gaps and shortfalls in insects



Cardoso *et al.* (2011). The seven impediments in invertebrate conservation and how to overcome them. Biol. Cons. **144**

European Funding partition





There are important knowledge gaps and shortfalls that hinder our understanding of insect biodiversity

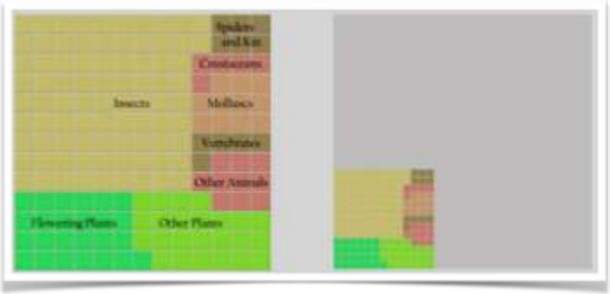
- Linnean shortfall (Number of sp)
- Wallacean shortfall (Distribution of sp)
- Darwinian shortfall (Evolution)
- Raunkiaerian shortfall (Sp traits and ecological functions)
- Community ecology gap

Hortal et al. (2015). Annu Rev. Ecol. Evol Syst. **46**

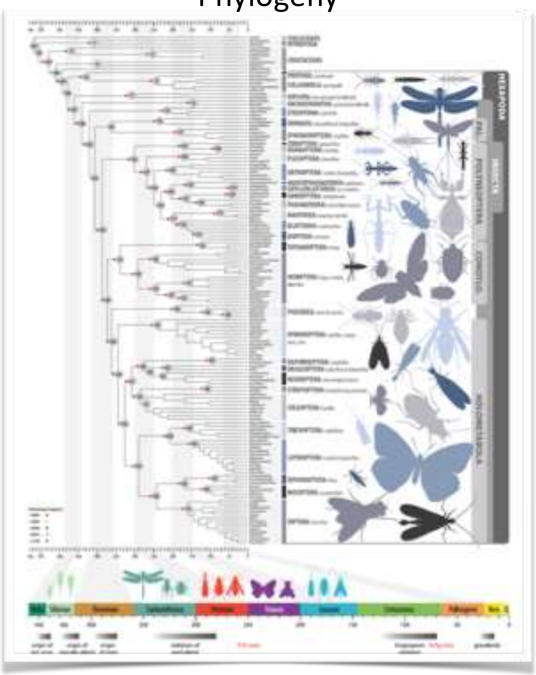
INTRODUCTION

How to address the shortfalls?

Taxonomy

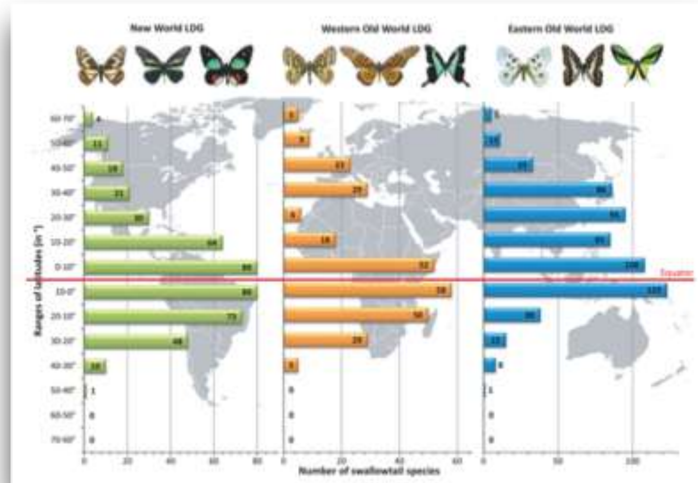


Phylogeny



Misof et al. (2014). *Science* **346**

Biogeography

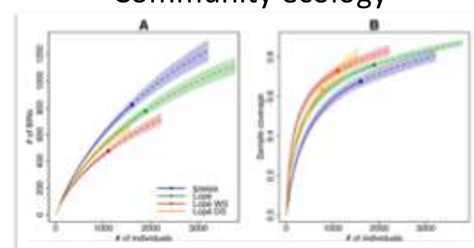


Condamine *et al.* (2012). *Ecology letters* 15

Population genetics

Life-histories & traits

Community ecology



Saturniid and sphingid moths as novel models for the study of insect diversity and macroecology

- INTRODUCTION
- **SATURNIID & SPHINGID MOTHS AS NEW MODELS**
- ADVANCES IN SYNTHESIS OF INFORMATION
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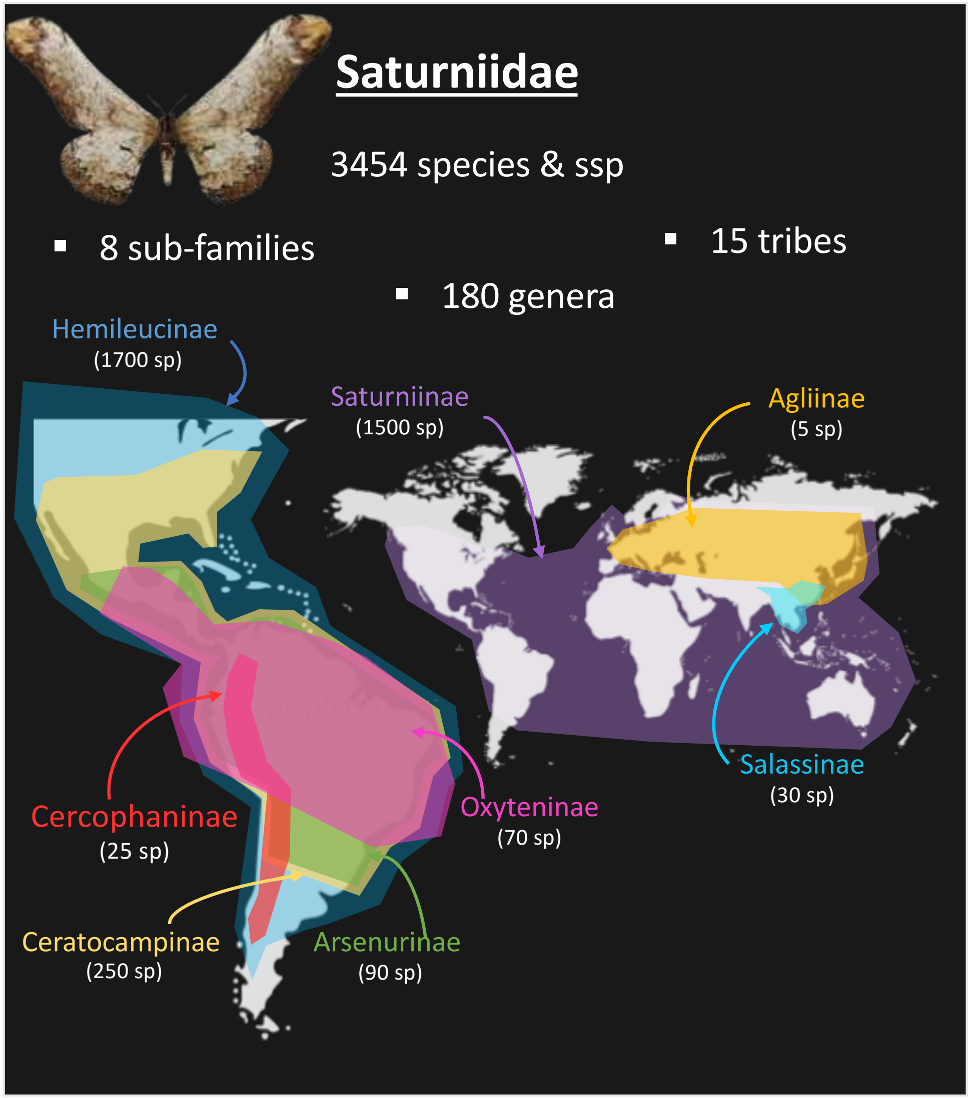
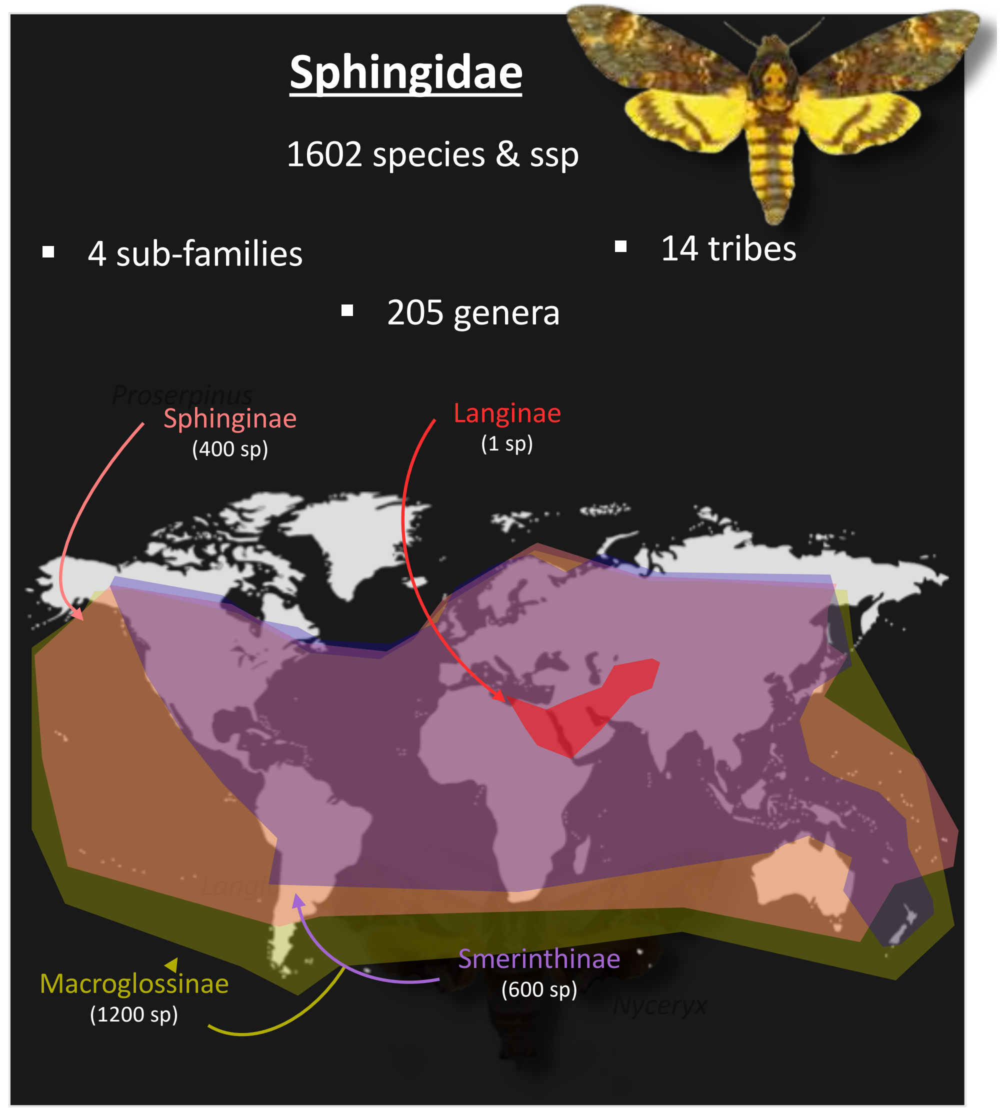
SATURNIID & SPHINGID MOTHS AS NEW MODELS

- Intermediate species richness (ca. 5000 sp.)
- Global distribution
- Very popular among collectors, many records! (occurrences)


Saturniidae
3454 species & ssp
▪ 8 sub-families
▪ 15 tribes
▪ 180 genera
Hemileucinae
(1700 sp)
Saturniinae
(1500 sp)
Agliinae
(5 sp)
Salassinae
(30 sp)
Oxyteninae
(70 sp)
Cercophaninae
(25 sp)
Ceratocampinae
(250 sp)
Arsenurinae
(90 sp)

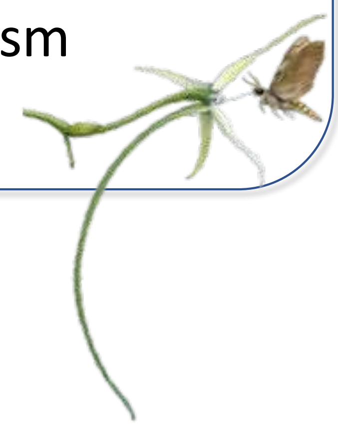

Sphingidae
1602 species & ssp
▪ 4 sub-families
▪ 14 tribes
▪ 205 genera
Sphinginae
(400 sp)
Langinae
(1 sp)
Macroglossinae
(1200 sp)
Smerinthinae
(600 sp)

<u>Saturniidae</u>

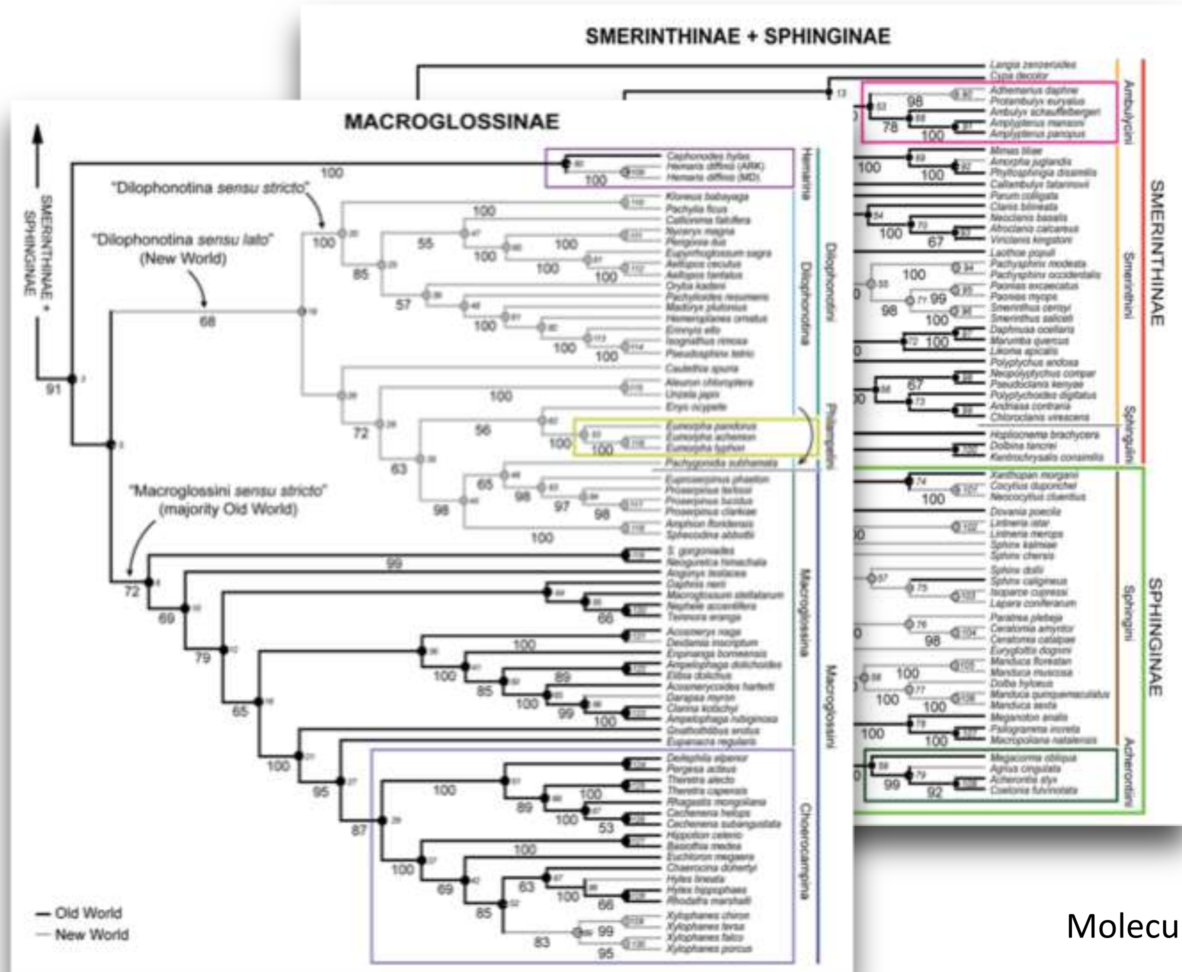
- Most species do not feed when adults
- Relatively low flying capacities
- Short adult lifespan
- Mostly Generalist caterpillars
- Sexual dimorphism

<u>Sphingidae</u>

- Wide spectrum in feeding habits
- High flying capacities
- Longer adult lifespan
- Mostly specialist caterpillars
- Low sexual dimorphism

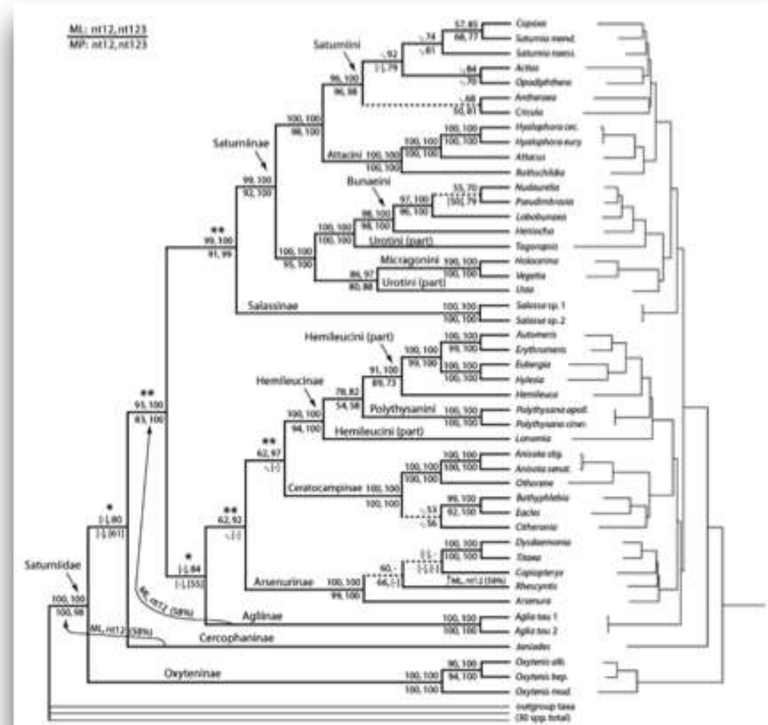


SATURNIID & SPHINGID MOTHS AS NEW MODELS



Kawahara *et al.* (2009). *PLoSOne 4*

SATURNIIDAE



Regier *et al.* (2008). *Syst. Ent.* 33

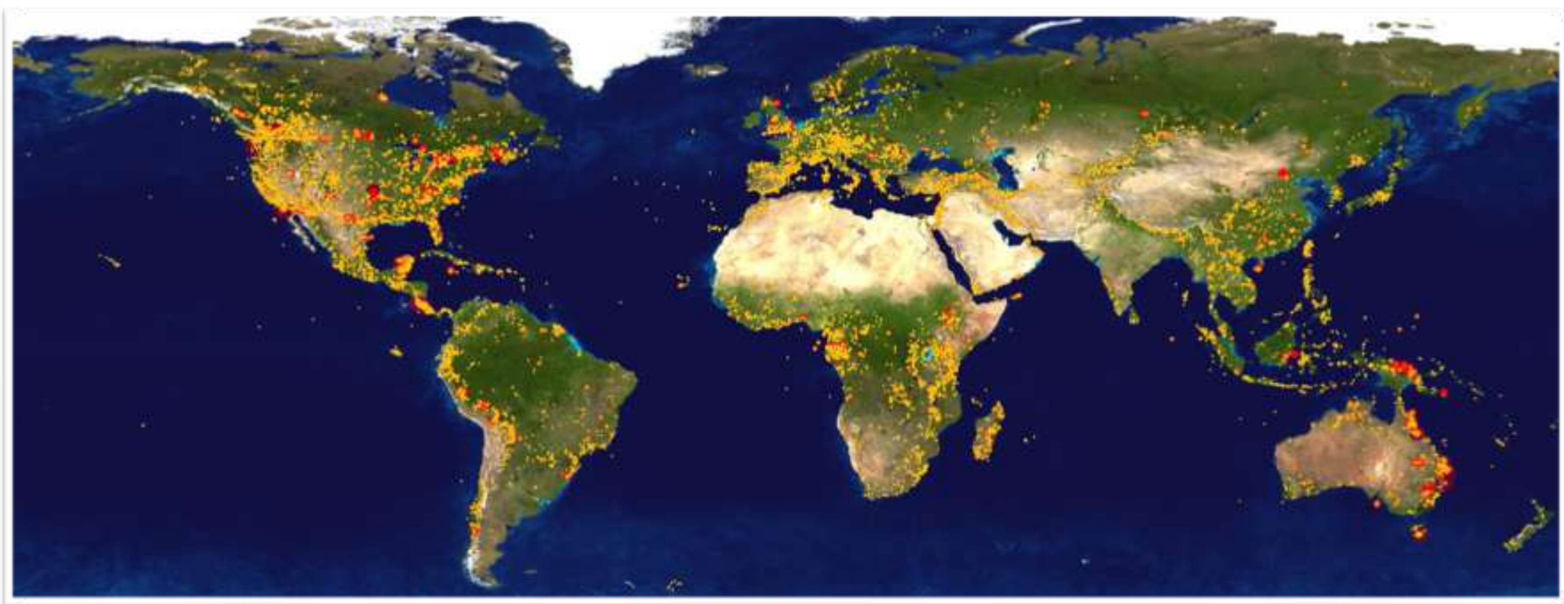
Molecular phylogenies (5 coding genes)

SATURNIID & SPHINGID MOTHS AS NEW MODELS

Comprehensive DNA barcode libraries have been compiled

Saturniidae: 48 391 DNA barcodes for 3466 species

Sphingidae: 29 251 DNA barcodes for 1708 species



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ADVANCES IN SYNTHESIS OF INFORMATION

Tackling Linnean shortfall

Taxonomy / checklist


A global checklist of the Bombycoidea (Insecta: Lepidoptera)

Ian J Kitching[¶], Rodolphe Rougerie[§], Andreas Zwick[|], Chris A Hamilton[¶], Ryan A St Laurent[¶], Stefan Naumann[#], Liliana Ballesteros Mejia[§,¤], Akito Y Kawahara[¶]

Kitching *et al.* (2018) *BDJ* 6: e22236

10 353 names listed for both families

Sphingidae: 205 genera, 1602 sp. & ssp.
(+250 sp. in past 10 years)

Saturniidae: 180 genera, 3454 sp. & ssp.
(+1500 sp. in past 10 years)

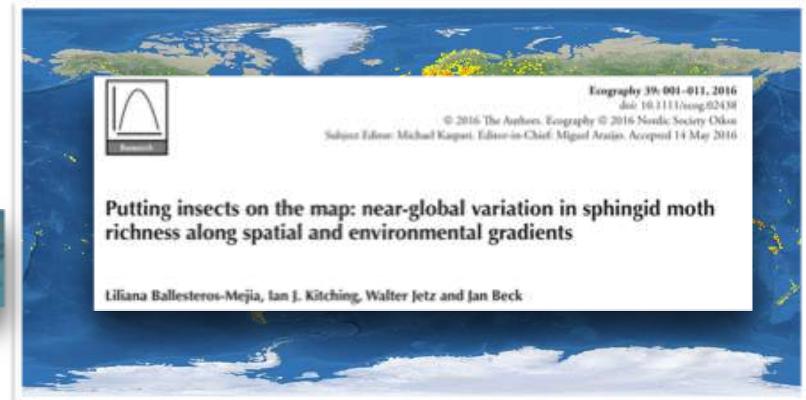
ACTIAS
database

Data compilation
(e.g. Lemaire collection, MNHN)

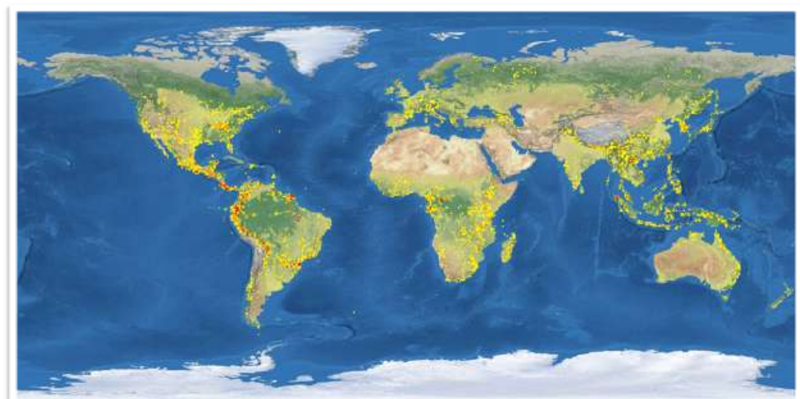
Data aggregation
(e.g. Ballesteros et al. 2016; GBIF)

Tackling Wallacean shortfall

Distribution records

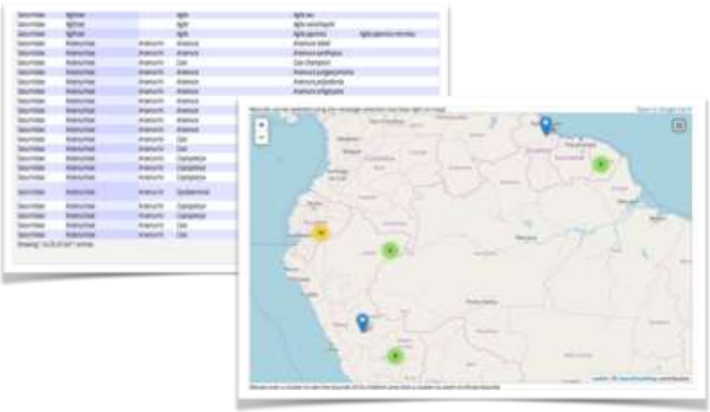


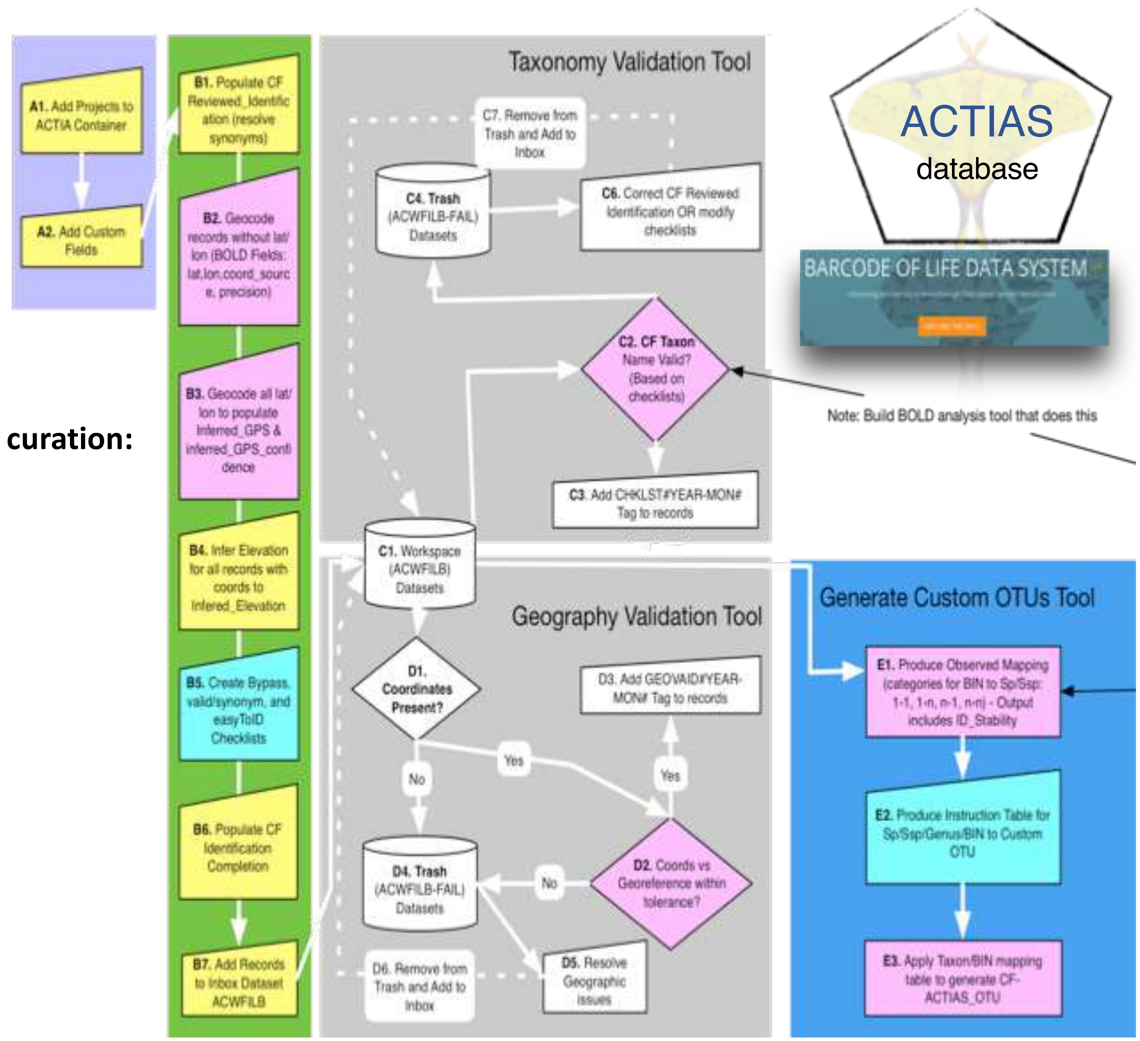
Sphingidae: 185 867 records (29 251 with barcodes)



Saturniidae: 95 410 records (48 391 with barcodes)

ADVANCES IN SYNTHESIS OF INFORMATION





Designing and implementation of a dedicated workflow for data curation:

Nomenclature, Geography and Taxonomic Reconciliation

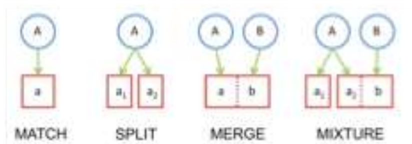
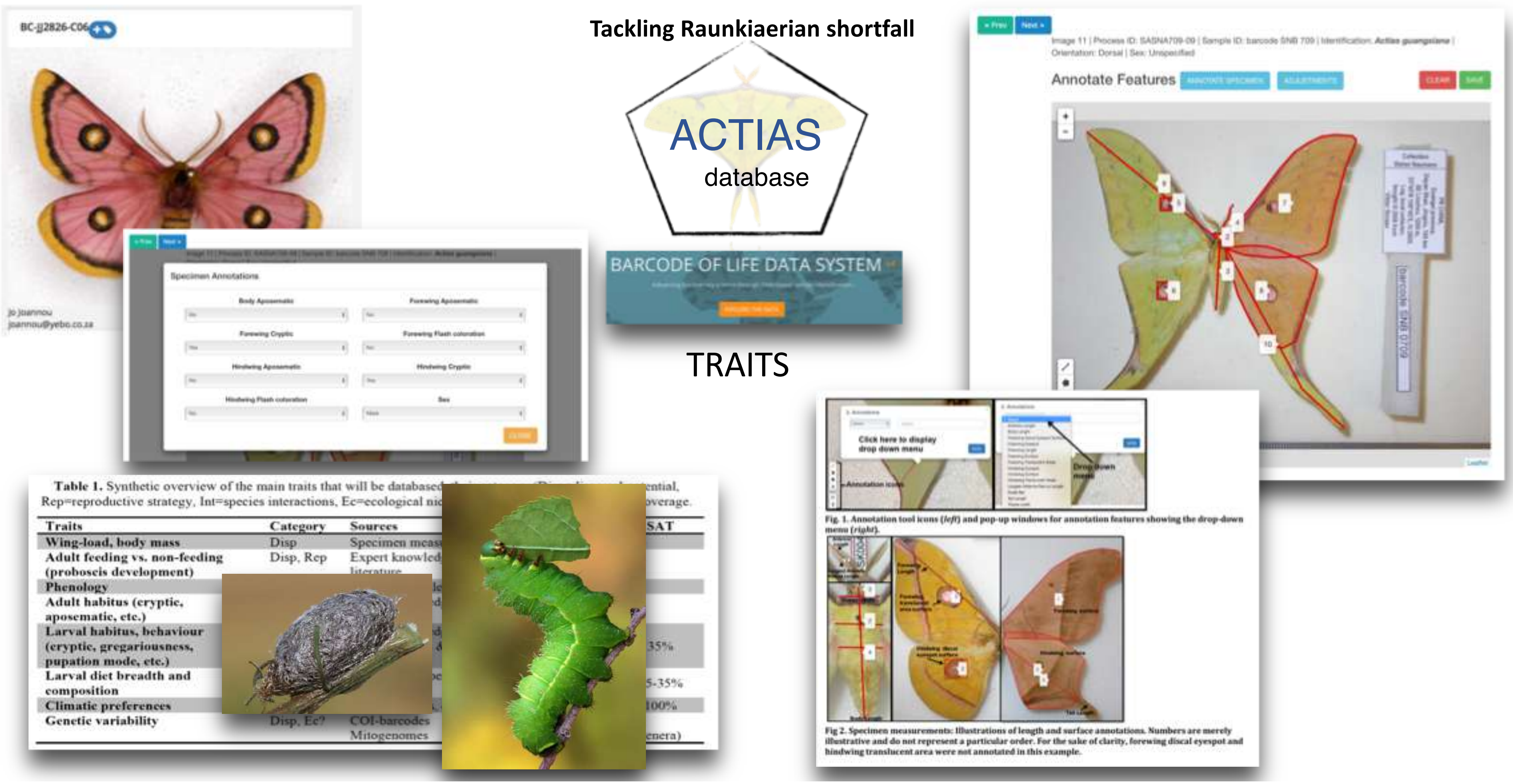


Figure 1. Possible patterns of association between species and BINs. Although just two species are considered, they enable illustration of the four possible patterns of association.
doi:10.1371/journal.pone.0066213.g001

ACTIAS_OTU

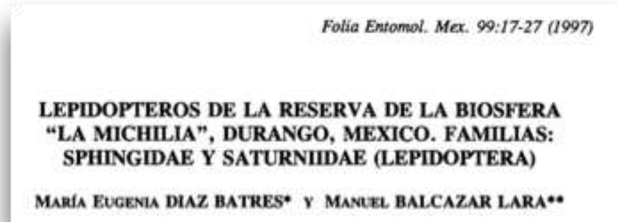
ADVANCES IN SYNTHESIS OF INFORMATION



ADVANCES IN SYNTHESIS OF INFORMATION

Tackling community ecology gap

Literature surveys


Folia Entomol. Mex. 99:17-27 (1997)

LEPIDOPTEROS DE LA RESERVA DE LA BIOSFERA "LA MICHILIA", DURANGO, MEXICO. FAMILIAS: SPHINGIDAE Y SATURNIIDAE (LEPIDOPTERA)

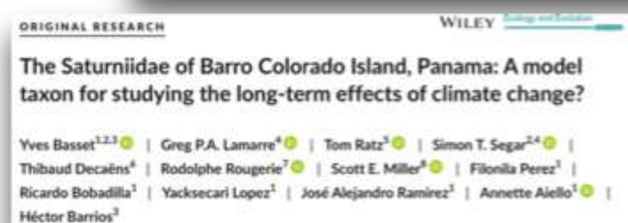
MARÍA EUGENIA DIAZ BATRES* Y MANUEL BALCAZAR LARA**


ARTÍCULO ORIGINAL

Diversidad de los ensambles de esfíngidos (Lepidoptera: Sphingidae) de un bosque siempreverde mesófilo, Sierra del Rosario, Cuba

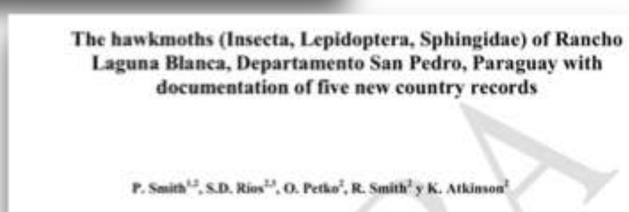
Diversity of hawkmoth's assemble (Lepidoptera: Sphingidae) in an evergreen forest, Sierra del Rosario, Cuba

Daryl David Cruz Flores[1] y Alejandro Barro Cañamero[2*]

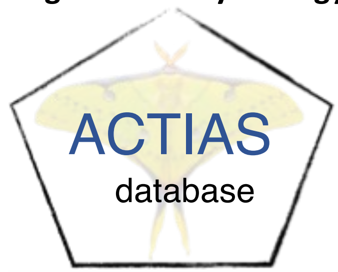

ORIGINAL RESEARCH   WILEY

The Saturniidae of Barro Colorado Island, Panama: A model taxon for studying the long-term effects of climate change?

Yves Basset[1,2,3] | Greg P.A. Lamarre[4] | Tom Ratz[5] | Simon T. Segar[2,4] | Thibaud Decaëns[6] | Rodolphe Rougerie[7] | Scott E. Miller[8] | Filonila Perez[1] | Ricardo Bobadilla[1] | Yacksecari Lopez[1] | José Alejandro Ramirez[1] | Annette Aiello[1] | Héctor Barrios[3]

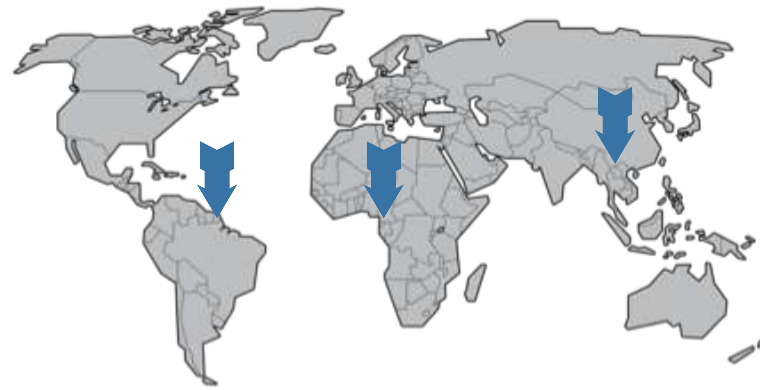

The hawkmoths (Insecta, Lepidoptera, Sphingidae) of Rancho Laguna Blanca, Departamento San Pedro, Paraguay with documentation of five new country records

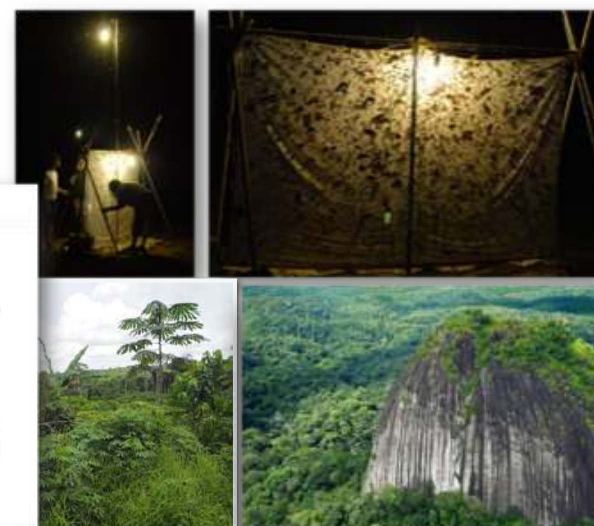
P. Smith[1,2], S.D. Rios[2,3], O. Petko[2], R. Smith[2] y K. Atkinson[2]



Community composition

Fieldwork/DNA metabarcoding
(responses to habitat change)





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Latitudinal gradient of Diversity

The most pervasive pattern of life on earth……

We know that there are more species in the tropics…… BUT

The most obvious question and yet the most elusive answer

UNDERSTANDING PATTERNS

How many species are there in the Tropics?

Taxonomical descriptions are not as fashionable anymore (early 20th century).

A combination of molecular information (i.e. DNA barcodes) and integrative taxonomy is changing lately the taxonomy of insects. They have also revealed many cryptic species (most of them in the tropics)

Recent inflation in species number: <u>Sat</u> 1500sp ; <u>Sph</u> 250sp (more waiting to be described!)

Uncertainty in species identification especially for historical records.

Great wealth of barcodes data after 10 years sampling ready to be used.

<u>Estimating species richness from barcodes</u>

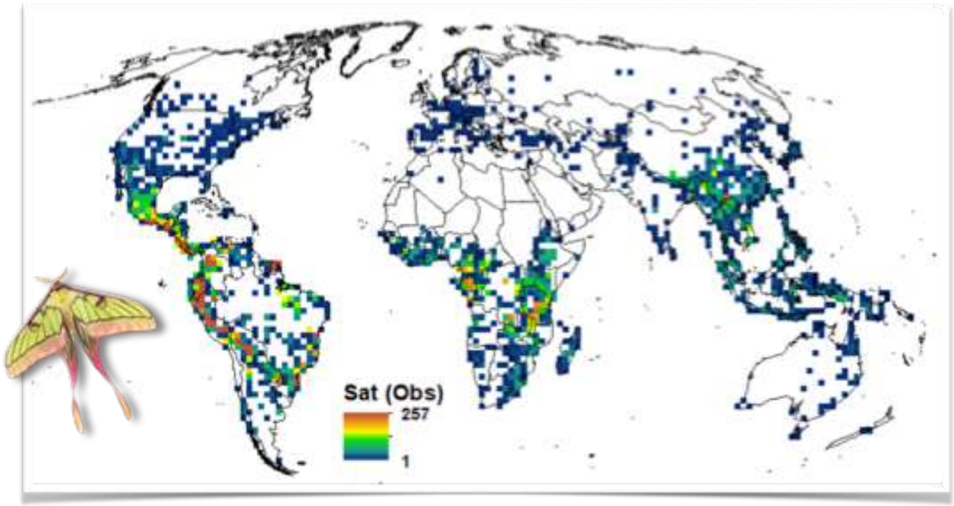
Does it correlate with previously published estimates?

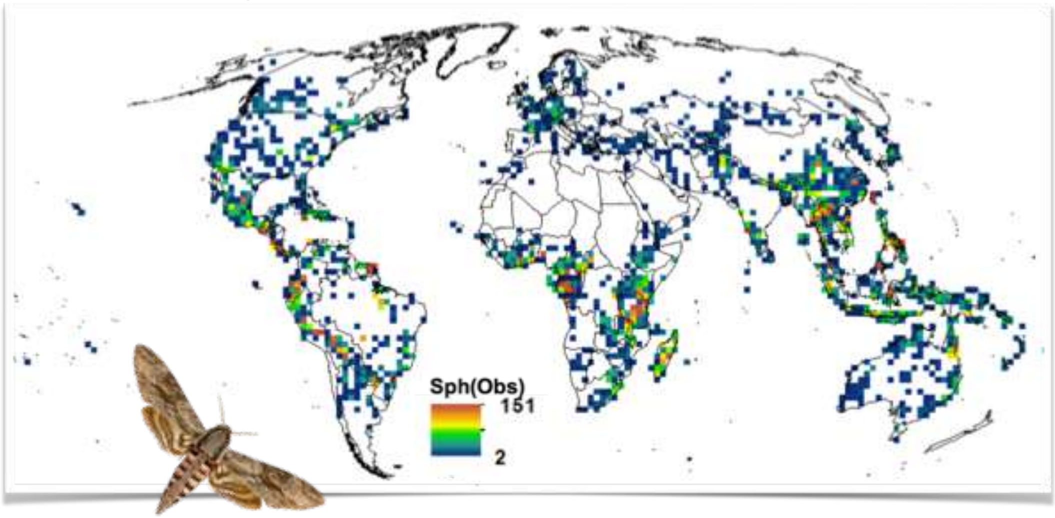
UNDERSTANDING PATTERNS

	Saturniidae	Sphingidae
Number of records	46117	26096
Number of unique records	25716	15090
Number of BINS	4141	1940

BIN = Barcode Index Number, as proxy for species

Using DNA BARCODES: Balance between more accurate account of species diversity vs more limited sample size (30%)





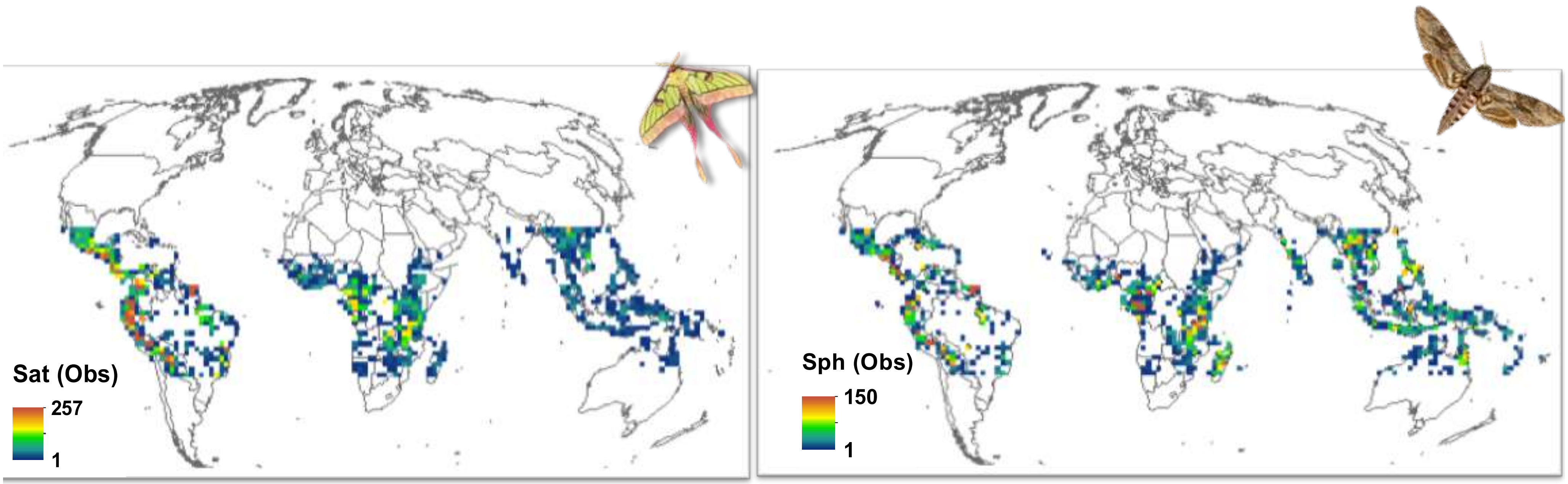
Observed richness at 200km cell-size

UNDERSTANDING PATTERNS

How many species are there in the tropics and where are they?

	Saturniidae	Sphingidae
Number of records	93% (43333)	85% (22404)
Number of BINS	96% (3995)	94% (1829)

BIN = Barcode Index Number, as proxy for species

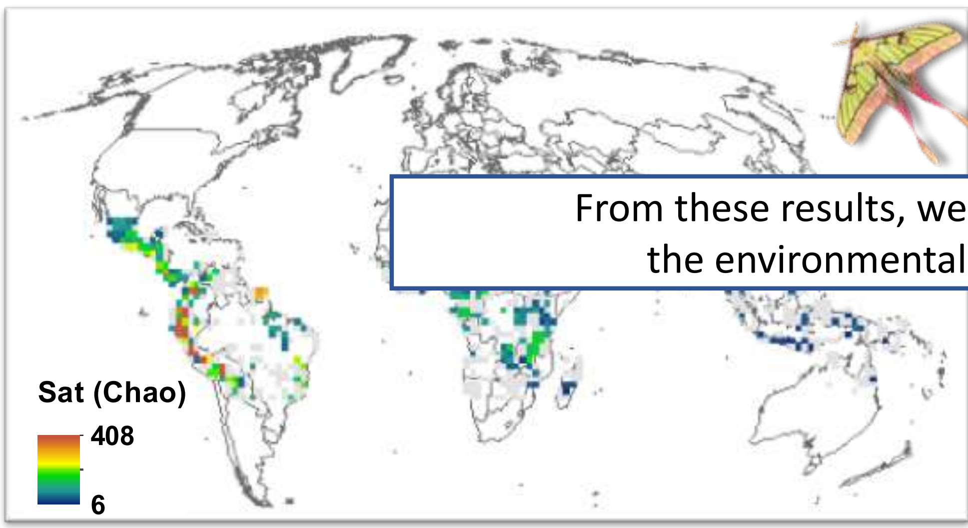


Observed richness at 200km cell-size

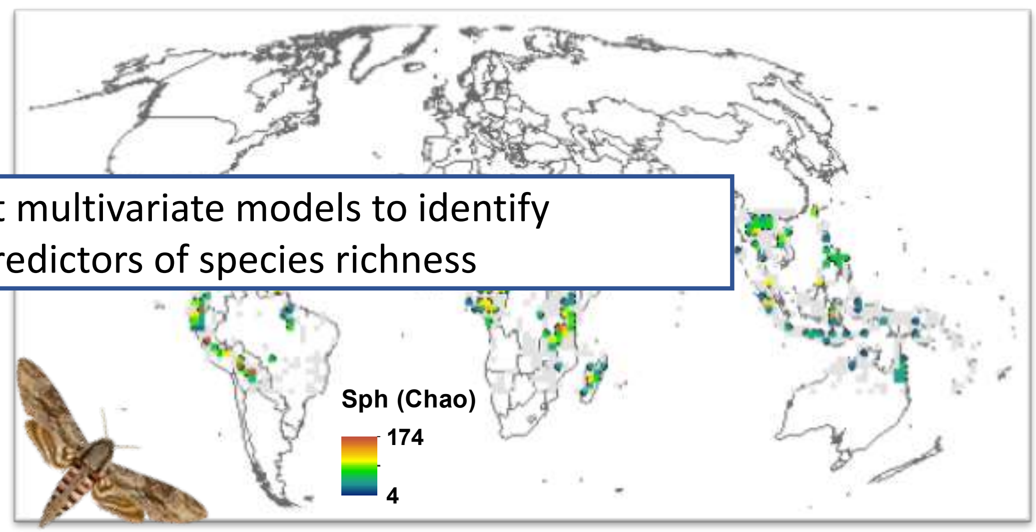
UNDERSTANDING PATTERNS

Estimating species richness in the tropics

Cell size	Saturniidae (# Cells)			Sphingidae (# Cells)		
	Tropics	With data	25rec	Tropics	With data	25rec
200	1272	702	**236**	1272	679	**147**

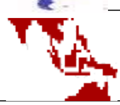


From these results, we fit multivariate models to identify the environmental predictors of species richness



Chao1 estimators at 200km cell-size
Used as response variable

UNDERSTANDING PATTERNS

	$Log_{10}S_{chao}$ N= 236 cells. (Pseudo-R^2 = 0.742)		
	Coefficient	**T-value**	**P-value**
Intercept	1.053	0.105	0.000
	**0.058**	**0.021**	**0.007**
	**0.091**	**0.021**	**0.000**
	0.019	0.021	0.358
	**0.491**	**0.127**	**0.000**
	**0.619**	**0.165**	**0.000**
	**0.850**	**0.122**	**0.000**
	**0.282**	**0.120**	**0.020**

<u>Identified as drivers of richness</u>

Altitudinal range: Topographic heterogeneity

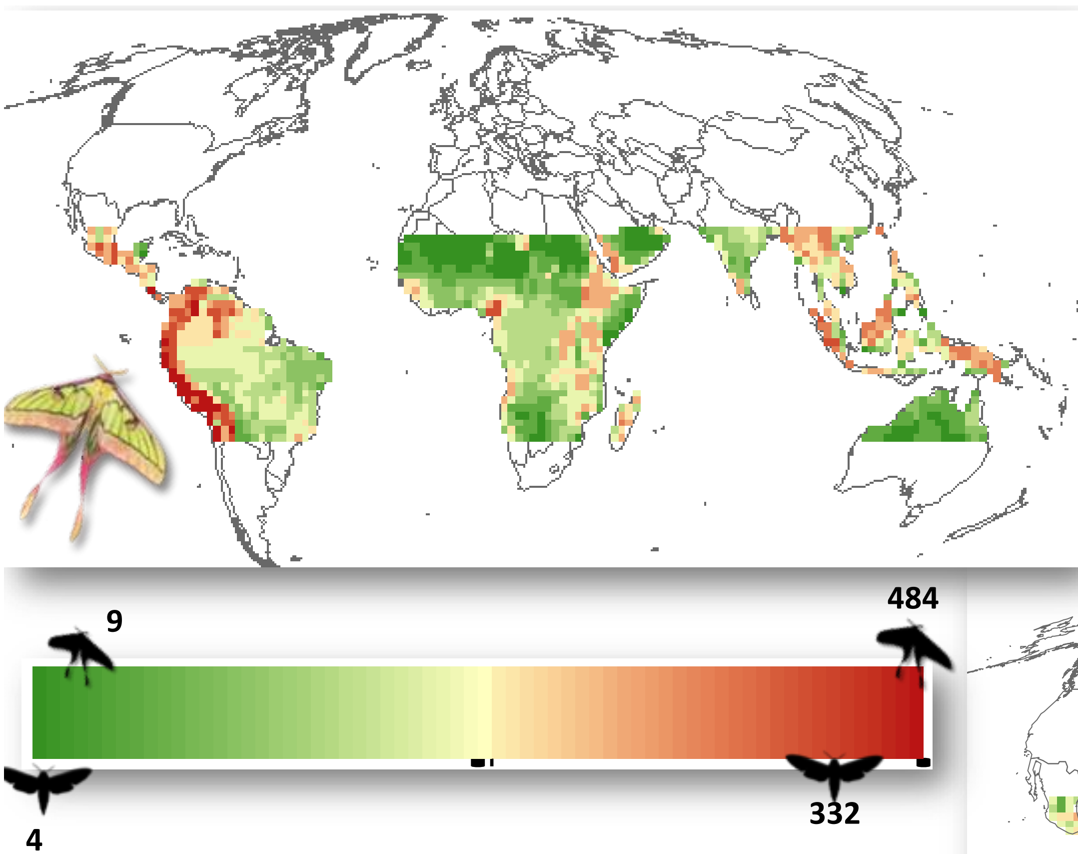
Annual mean Precipitation : Precipitation variation

Annual mean temperature: Temperature variation

Tree coverage (%): Herbivores insects

Biogeographical regions: Regional and historical factors

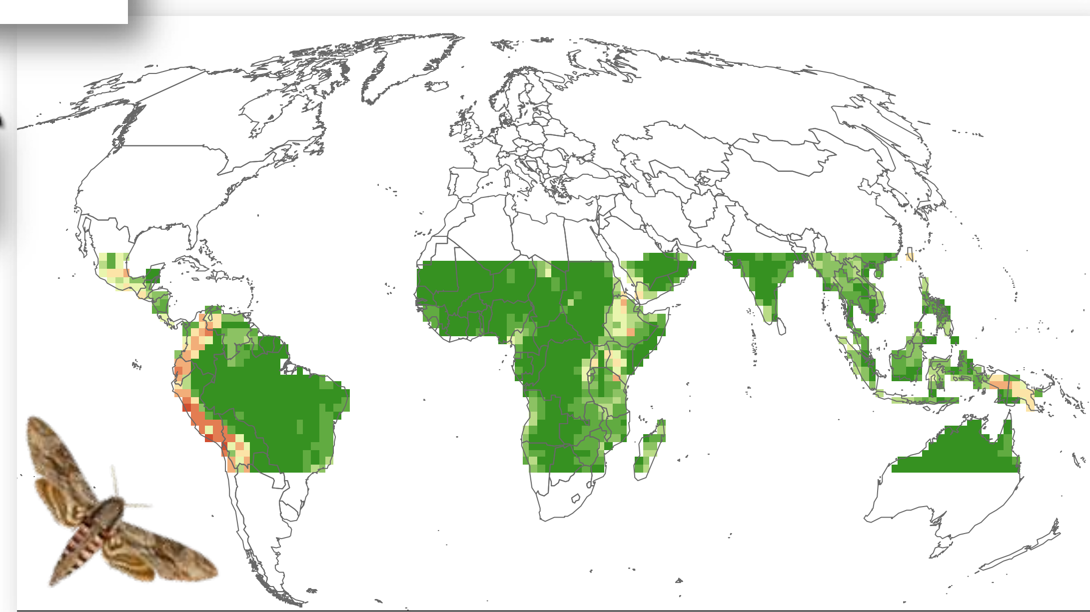
	$Log_{10}S_{chao}$ N= 147 cells. (Pseudo-R^2 = 0.45)		
	Coefficient	**T-value**	**P-value**
Intercept	1.367	17.947	0.000
	0.047	1.905	0.059
	**0.059**	**2.286**	**0.024**
	0.014	0.615	0.540
	**0.249**	**2.427**	**0.017**
	0.084	0.532	0.596
	**0.281**	**2.865**	**0.005**
	**0.249**	**2.634**	**0.009**



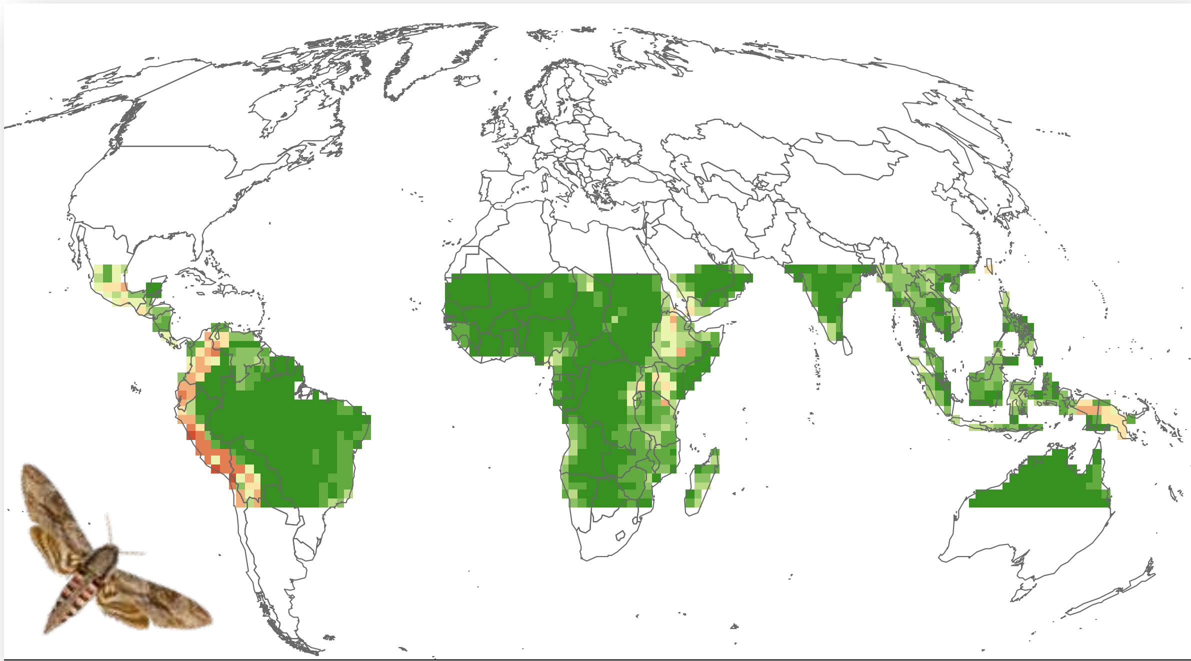
Neotropics as the richest for the two families. Andean part in South America, Venezuelan Amazonia, Lowland of Peru.

In the Afrotropics: East arc Mountains, Highlands of Cameroon, Forest areas of Guinea and Sierra Leone, Madagascar.

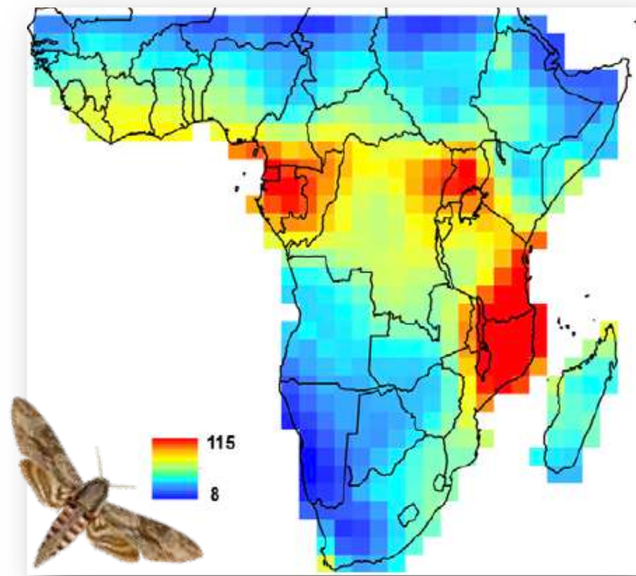
In the Asian tropics: Indo-Burma Hotspot, Sumatra, Borneo, Papua and New Guinea.



UNDERSTANDING PATTERNS



<u>Occurrence records</u>. $S_{chao25.}$
Pseudo-R^2 = 0.145 (n=146 cells)

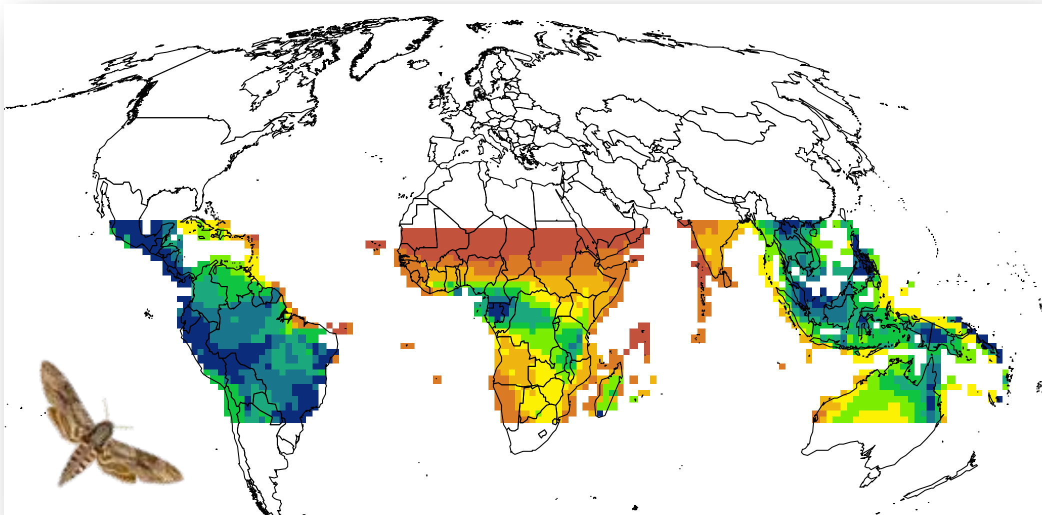


Pearson's r = <u>0.128</u> n= 450

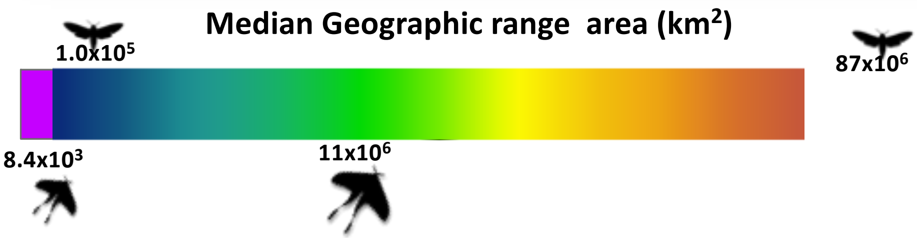
Ballesteros-Mejia *et al.* (2013) *Glob. Ecol. & Biogeo. 22*

UNDERSTANDING PATTERNS

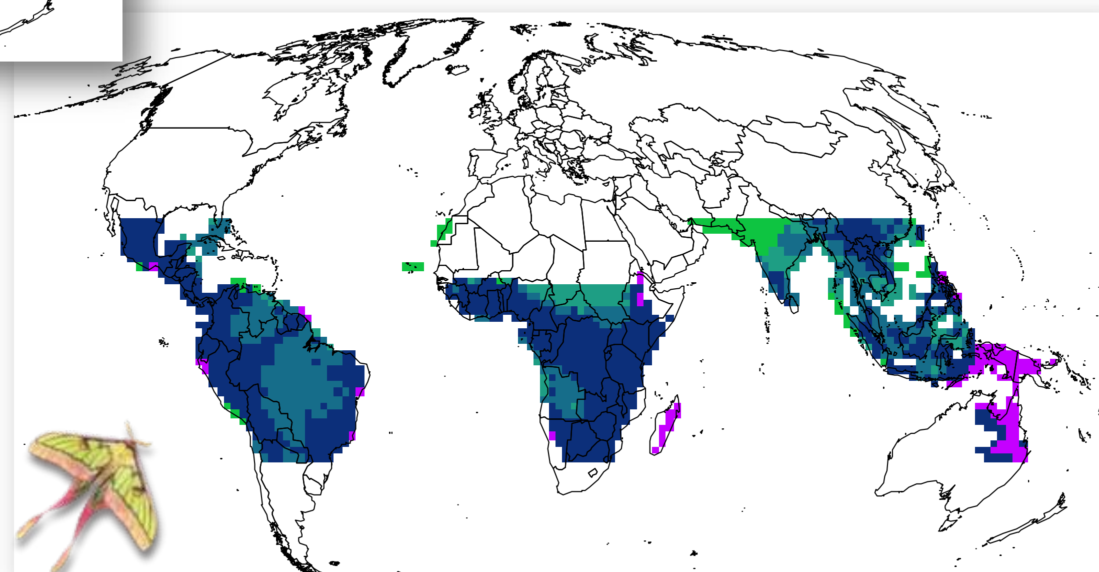
Macroecological analyses: distribution of species ranges (from BINs only)



Saturniids have <u>smaller ranges</u> than **Sphingids**
Species with narrow ranges often concentrated in biodiversity hotspot



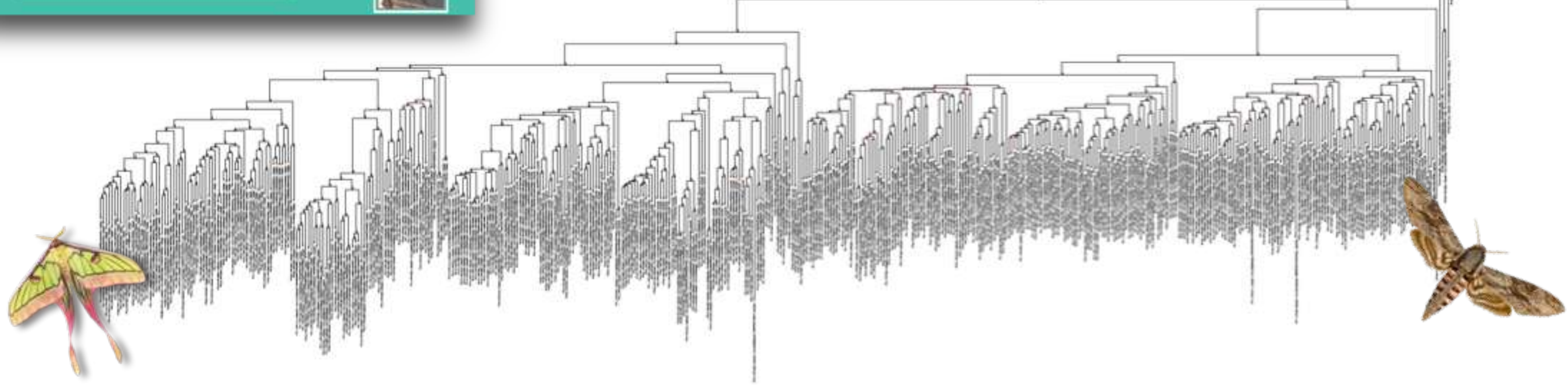
Saturniids 2441 BINS **<u>Sphingids</u>** 1245 BINS
Excluding <u>singletons</u> and <u>doubletons</u>



UNDERSTANDING PATTERNS

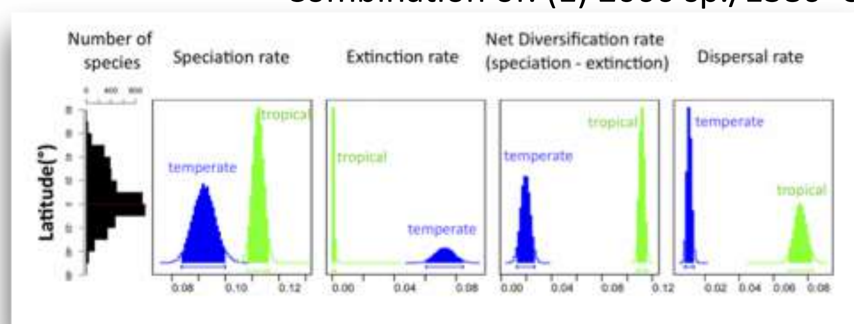
Evolutionary dimension

Phylogeny at genus level



<u>AIM:</u> First and most complete phylogeny for a group of insects

Combination of: (1) 2000 sp./1380 UCE loci dataset with (2) 5000+sp./DNA barcode dataset

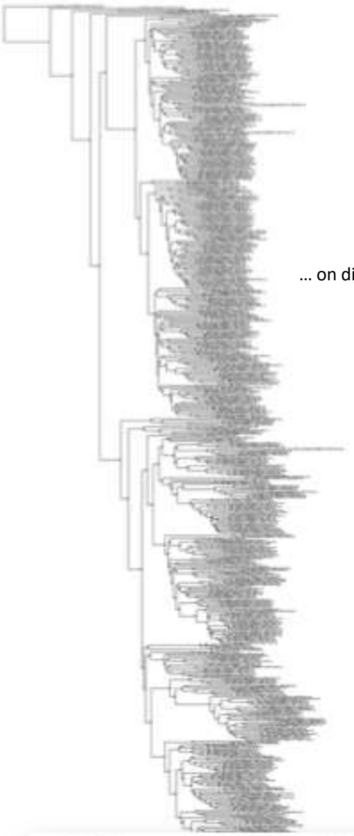


Rolland et al. 2014. PloS Biology 12(1): e1001775

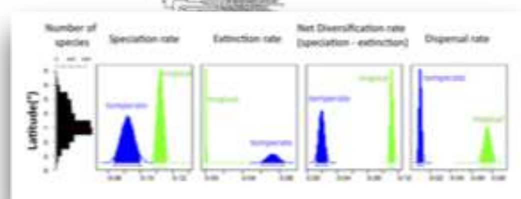
- Dated phylogeny
- Diversification analysis
- Historical biogeography

UNDERSTANDING PATTERNS

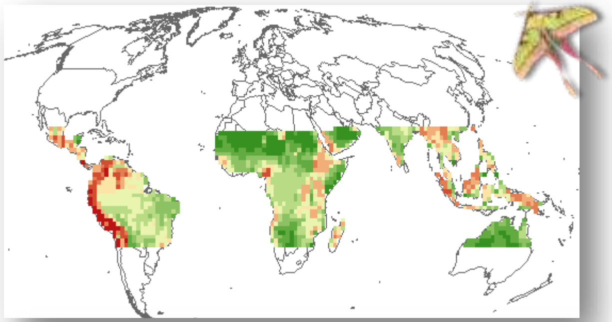
Role of traits

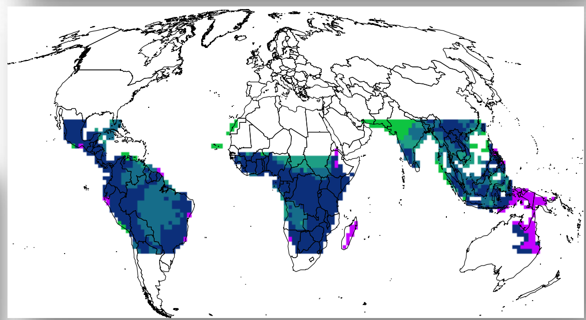


… on diversification dynamics



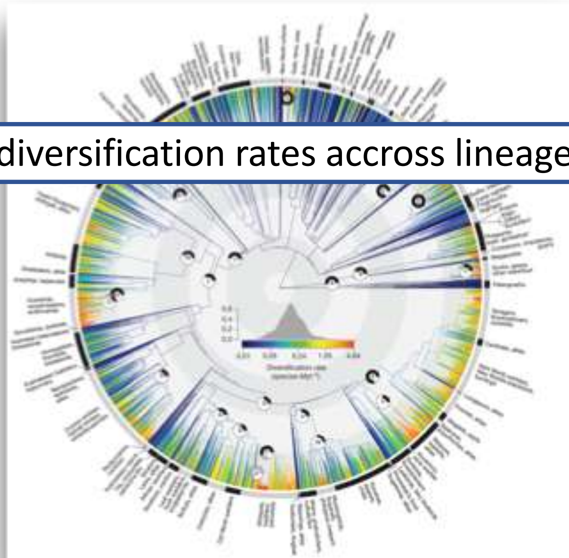
… on diversity patterns (richness, ranges, etc.)





UNDERSTANDING PATTERNS

Can…



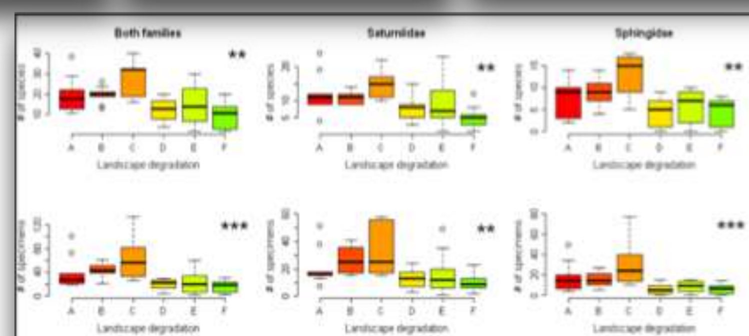
… diversification rates accross lineages…

… and/or species traits…

Community analyses

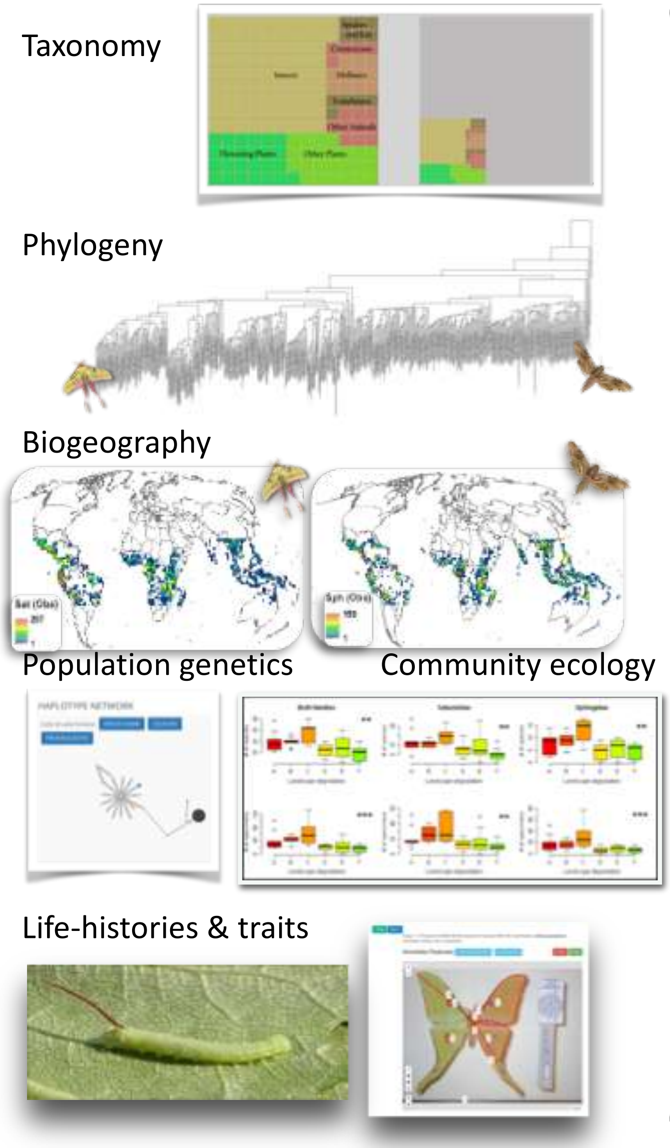
Responses of sphingid and saturniid moths to environmental changes

… inform how communities respond to environmental changes?



Saturniid and sphingid moths as novel models for the study of insect diversity and macroecology

- INTRODUCTION
- SATURNIID & SPHINGID MOTHS AS NEW MODELS
- ADVANCES IN SYNTHESIS OF INFORMATION
- UNDERSTANDING PATTERNS
- **TAKE HOME MESSAGE & PERSPECTIVE**



Take home messages

Fill up knowledge gaps at global scale for a group of insects

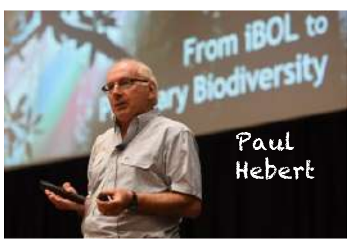
- Basic knowledge about insect diversity in space and time
- Understand, predict species responses to environmental changes
- Framework, workflow and tools made available for other groups

Perspectives

- Comparison to other groups (vertebrates, plants, etc.)
- Conservation biology:
    - highlight areas / taxa
    - evaluate current conservation framework
    - design new conservation strategies

ACKNOWLEDGEMENTS

Hélène
Morlon



All students (undergrads, master) and all contributors to the barcoding campaigns...

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FRB
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AGENCE NATIONALE DE LA RECHERCHE
ANR

MUSÉUM
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