Utilizing digitized specimen data to trace the history and predict the future for an economically important pest of commercial fruits

Crystal Klem, Alberto Zilli, and Jennifer Zaspel

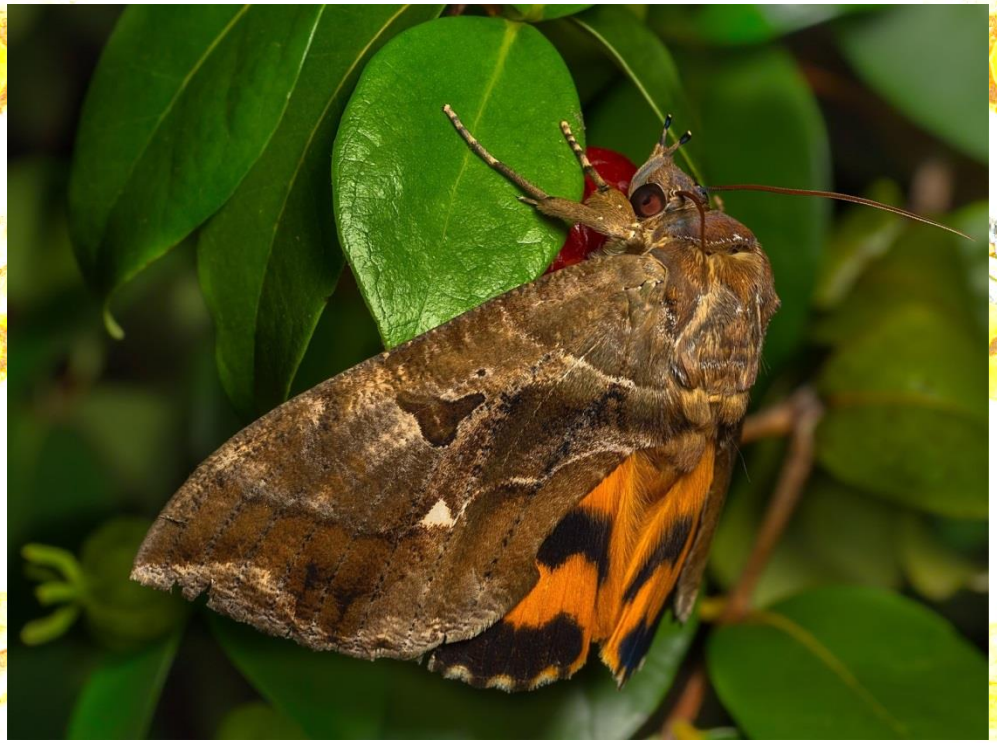


Photo courtesy of piggsy, https://www.mu-43.com/threads/night-hawks.90911/

Eudocima Billberg, 1820

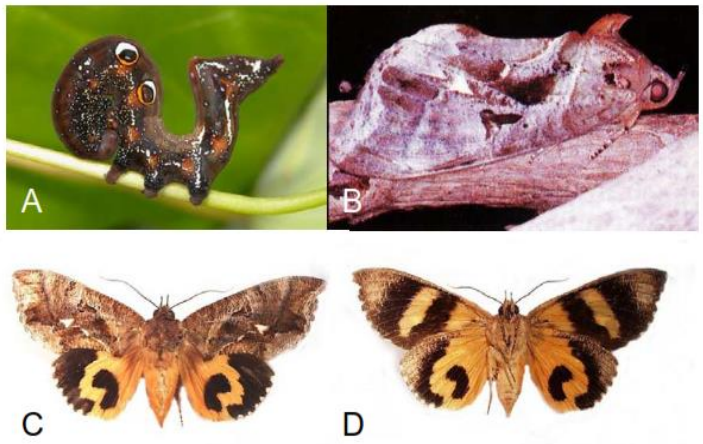
- Genus of fruit-piercing moths found across the Old and New World tropics
- Use saw-like proboscis to pierce over 50 varieties of fruits and nuts
- A single species can cause crop losses of more than 50%, 80-90% loss when ranges overlap (Fay 1996)
- Disagreement about classification and species delineation is persistant

Photos courtesy of the Home Bug Garden, Damon Ramsey, Julia Snyder

Video courtesy of Julia Snyder

Eudocima phalonia Linn., 1763

- Most notorious species in terms of agricultural significance
- High economic impact, current methods of control have low effectiveness
  - Bagging or netting fruit
  - Smoking orchards
  - Hand-netting with flashlights
  - Pheromone trapping



E. phalonia female, Davis et al. 2005

E. phalonia male

E. phalonia

- Widely distributed across Old World
  - African and Oriental tropics, SE Palearctic, Australia and Pacific
- Strongly suspected species complex
  - High morphological variability, many regional biotypes
  - Several close relatives recently characterized based on morphology

Photos courtesy of Julia Snyder

E. phalonia

E. lequeuxi
Brou & Zilli 2016

E. oliveri
Zilli et al. in press

E. steppingstonia
Zilli et al. in press

Needs

- Further clarification of the species complex could achieved by resolution of the group with molecular methods
- With at least 30 occurrences per location, meaningful inferences can be made for ecological niche modeling
  - http://symbiota4.acis.ufl.edu/scan/lepnet/portal/index.php
- Despite agricultural significance, no detailed range information is available for the *E. phalonia*-complex

Materials and Methods

- Collections visit to NHM, London
  - Approximately 2,000 pinned specimens digitized
  - iCollections equipment and workflow
    - http://www.nhm.ac.uk/our-science/our-work/digital-museum/digital-collections-programme/digitising-butterfly-moth-collections.html


BRUNEI 1618m
Bukit Retak
Montane forest
13-9-79
Lt. Col. M.G. Allen
Figured specimen
Moths of Borneo
Part 15 & 16
NHMUK 010201131

Specify Database - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View

PivotTable Table Picture Clip Art Shapes SmartArt Screenshot Column Line Pie Bar Sparklines Slicer Hyperlink Text Box Header & Footer Symbols

Tables Illustrations Charts Filter Links Text

W13

	O	P	Q	R	S	T	U	V	W	X	Y	
1	Collector I	Collector I	Verbatim	Country	State	County	Locality N	Elevation	Latitude1	Longitude	Remarks	Prep
2			27-30.vi.1	Fiji			Nandarivatu				G. Robinsc	pinn
3			31, 7.1971	New Caledonia			Mt. Aoupi	520 m	05298	76594	Site 62; B.	pinn
4			16-20.xii.1	Fiji			Nandarivatu				G. Robinsc	pinn
5			20/9/1969	Fiji			Savusavu				Brit. Mus.	pinn
6							Lancala					pinn
7			2-VI-53	Fiji			Viki Levu, Suva				B.M. 1953	pinn
8			1915		Nouv Hebrides		ile d'leba, Lolopuepue				Ex Oberth	pinn
9			17/6/1974.		New Hebrides		Pau Uma Is. Lehili				Othreis ful	pinn
10			Mar. & Apl. 1929		New Hebrides		Malekula, Oupua				B.M. 1929	pinn
11			iii. 1955.		New Hebrides		Aneityum,	1200 ft			B.M. 1955	pinn
12			iii. 1955.		New Hebrides		Aneityum,	1200 ft			B.M. 1955	pinn
13			2. iii. 1974.		New Hebrides		Paama I. [	1200 ft			Othreis ful	pinn
14			8 Jan. 01.		Florida I.						Rothschild	pinn
15			4. VI-9. VII.01.		Isabel I.						Rothschild	pinn
16			Mrch. 01				Kulambangra, Sol. Is.				Rothschild	pinn
17			4. VI-9. VII.01.		Isabel I.						Rothschild	pinn
18			Decemb. 07.				Arawa, Bougainville				Rothschild	pinn
19			1901		Florida I.		Solomon				ex. Janson	pinn
20			10.iii. 1955		Solomon Is.		Guadalcanal, Tanasu				Pres by Co	pinn
21			Jan. 01.		Florida I.						Rothschild	pinn
22			9-11 Nov. 1953		Solomon Is.		Rennell Is., Tingona				B.M. 1954	pinn
23			15.i.1955		Solomon Is.		Guadalcanal, H. Dist. Trenchota				Pres C.I.E.	pinn
24			Dec. 03. Jan. 04.		Solomons		Choiseul				Rothschild	pinn
25			March 1904.		Solomon Is.		New. Georgia				Rothschild	pinn
26			4. VI-9. VII.01.		Isabel I.						Rothschild	pinn
27			14-31. Oct. 1953		Solomon Is.		Rennell Is. Hutuna				B.M. 1954	pinn
28			IV. 01.				Guadalcanar				Rothschild	pinn
29			15.VIII.1901		Treasury I.						Rothschild	pinn
30			15.VIII.1901		Treasury I.						Rothschild	pinn
31				New Ireland							79-16	pinn

Montreal SMIRC Sheet3

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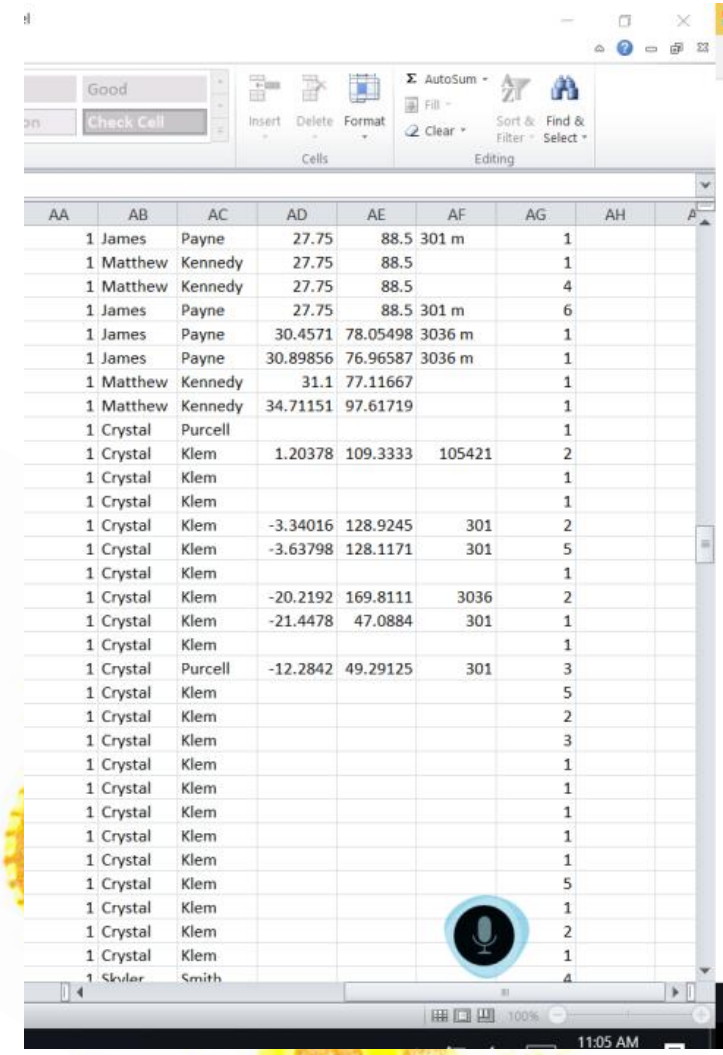

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1	James	Payne	30.89856	76.96587	3036 m	1	
1	Matthew	Kennedy	31.1	77.11667		1	
1	Matthew	Kennedy	34.71151	97.61719		1	
1	Crystal	Purcell				1	
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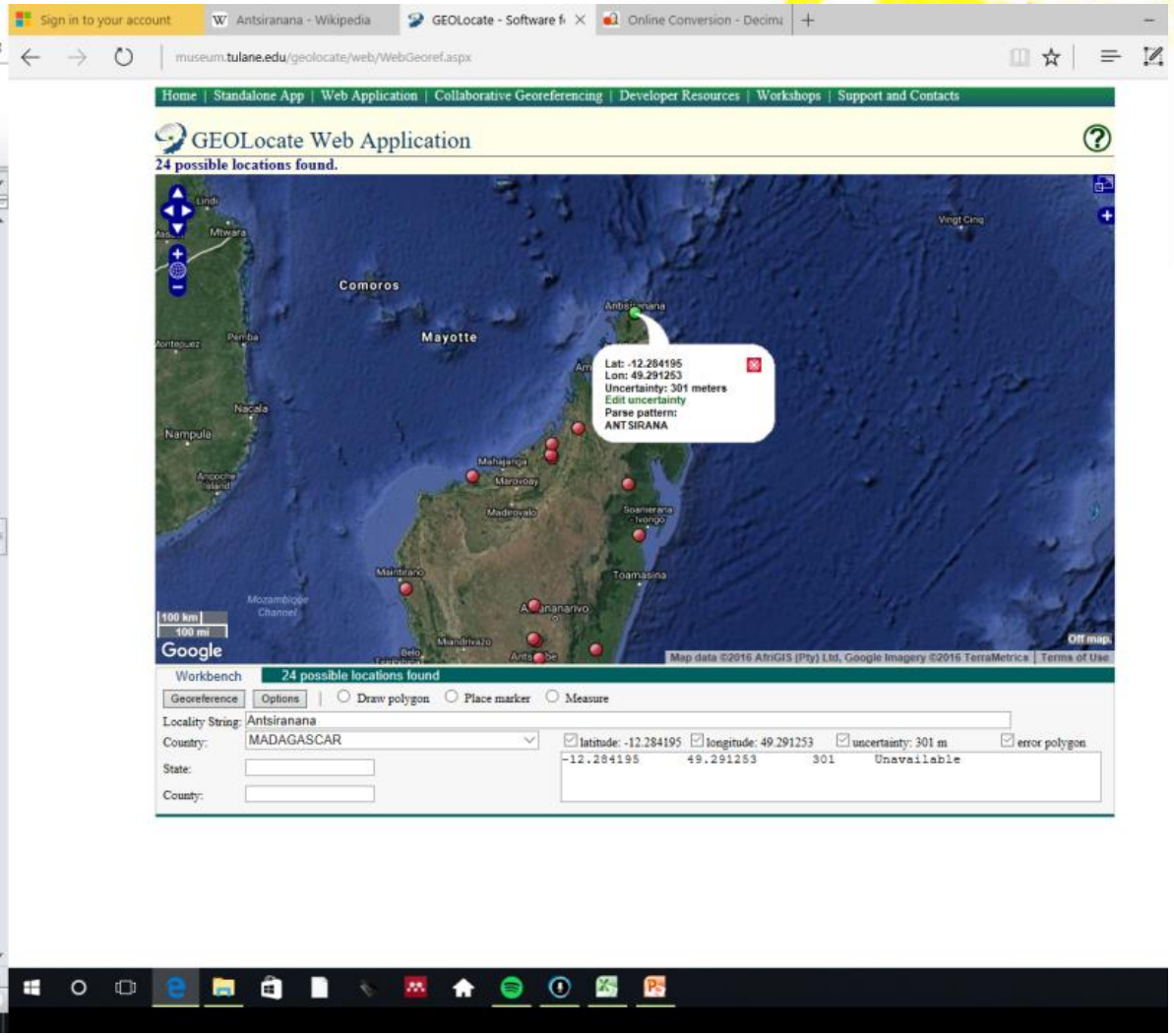

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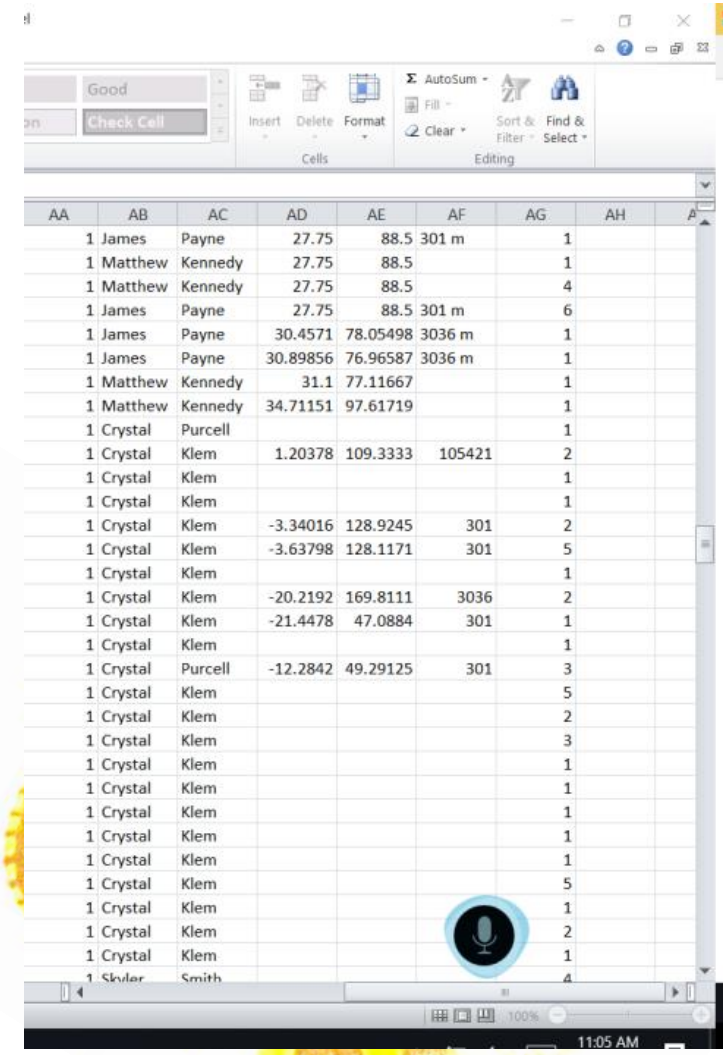

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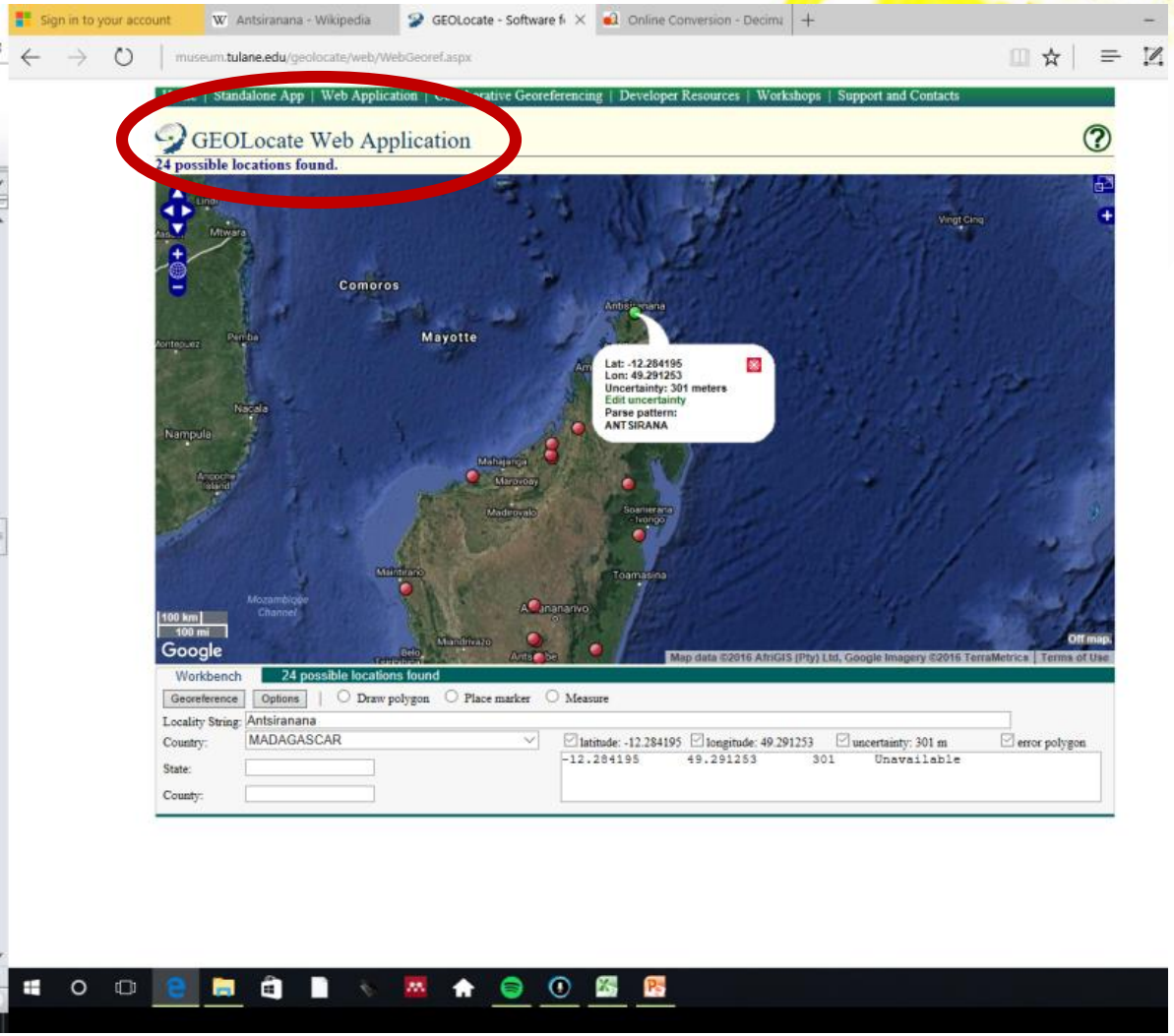

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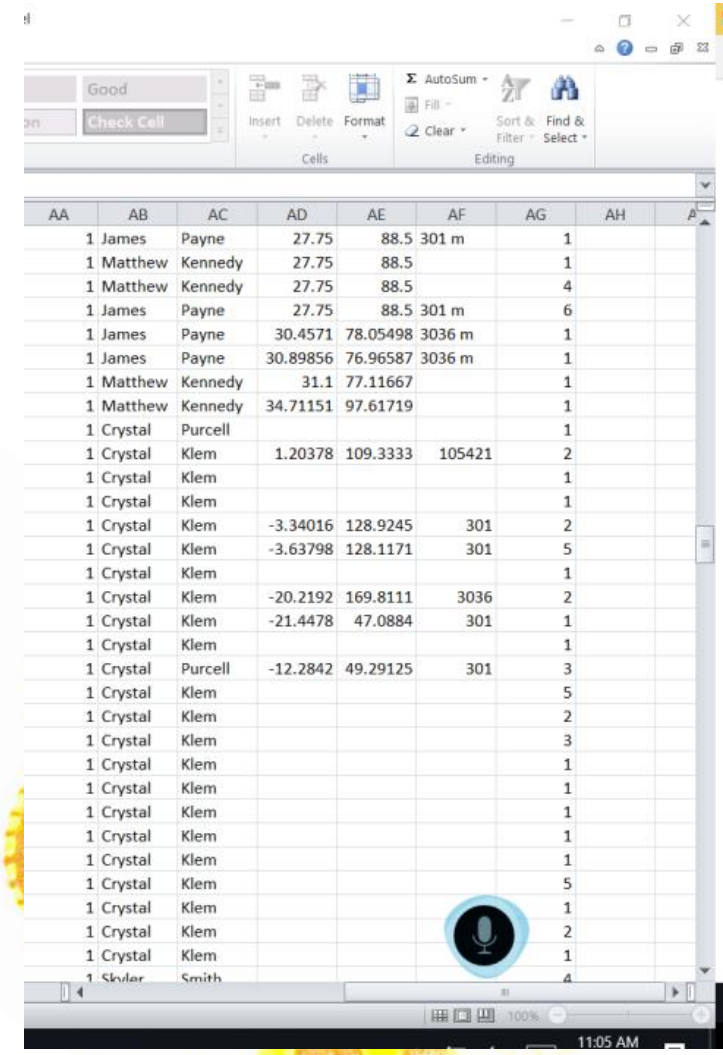

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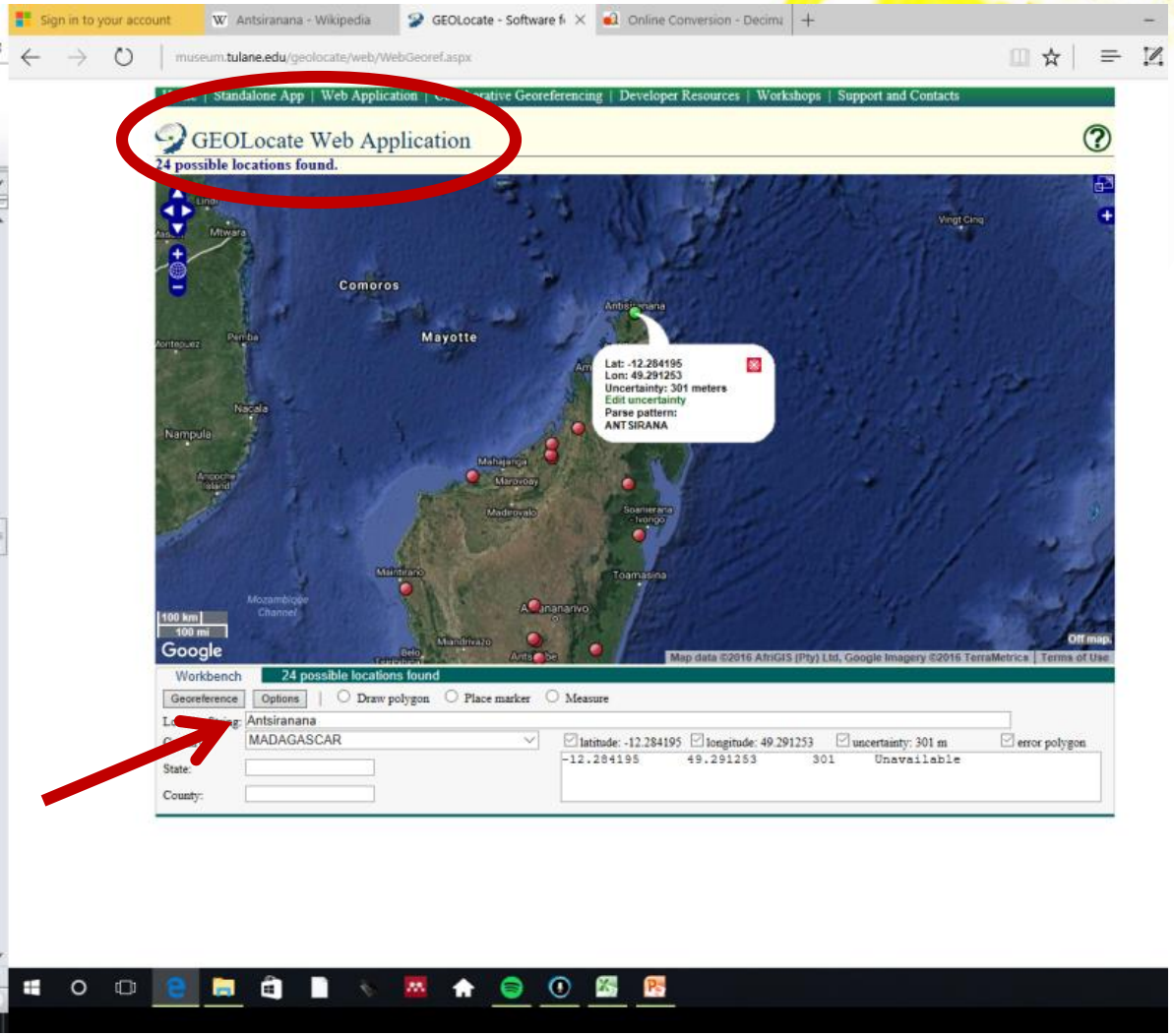

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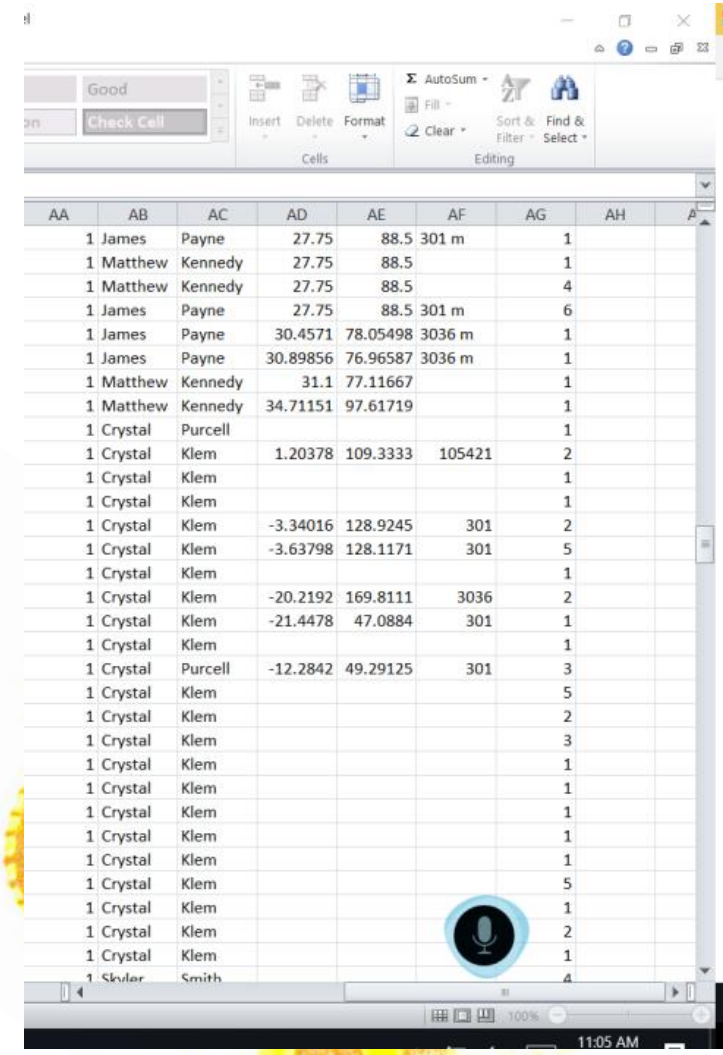

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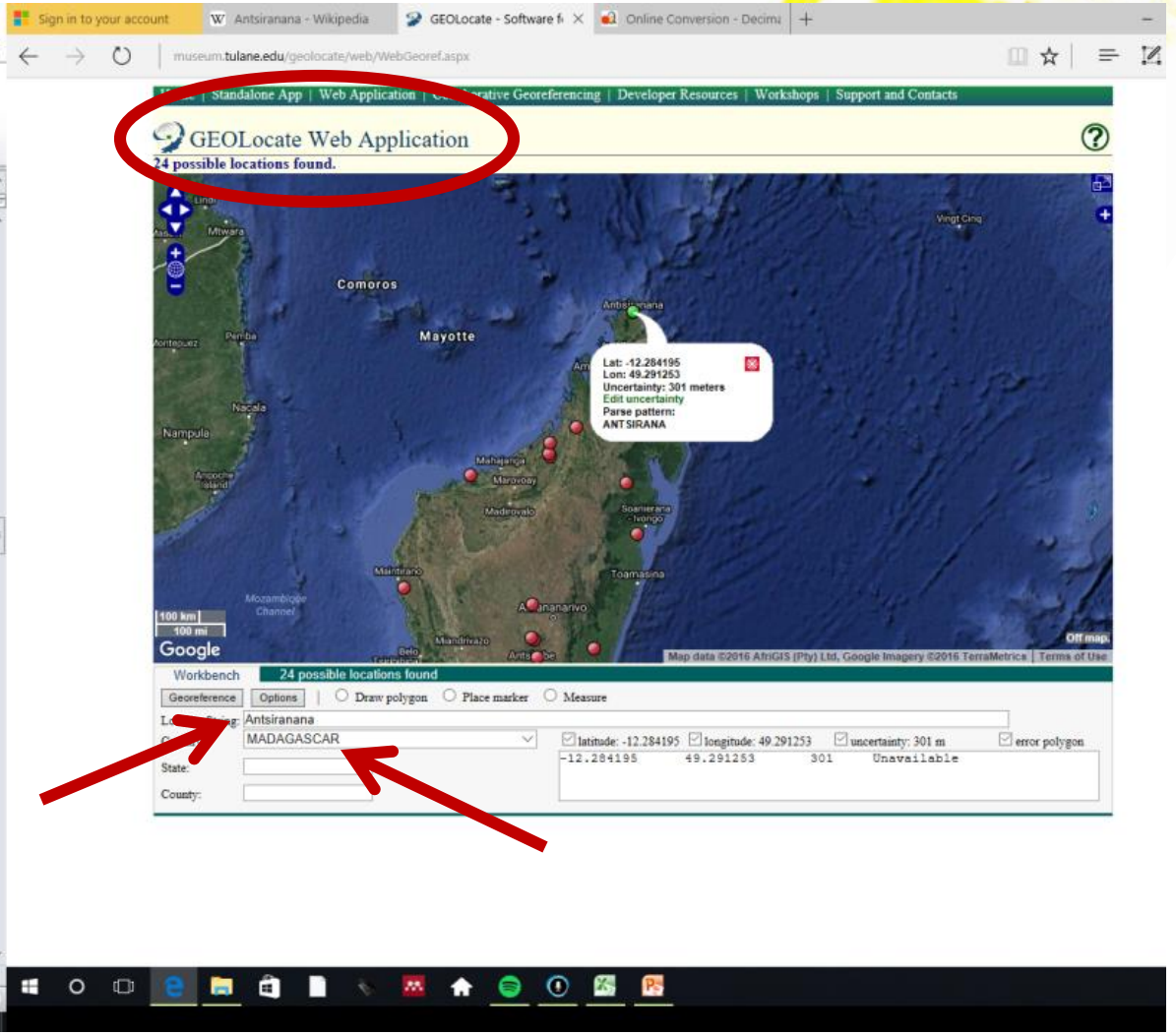

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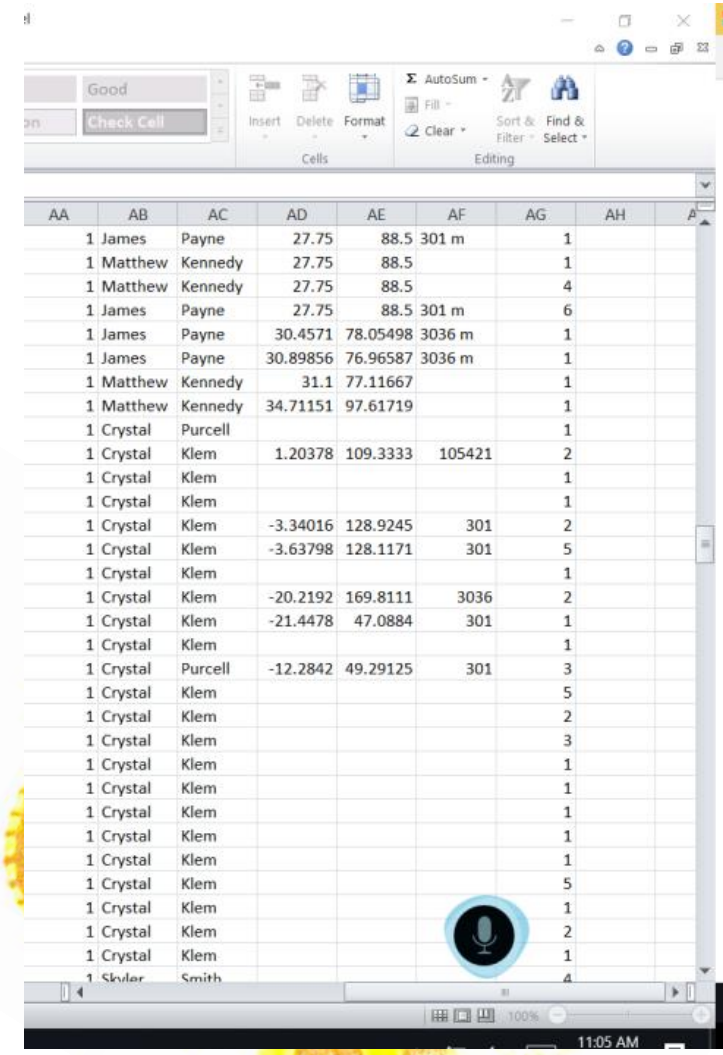

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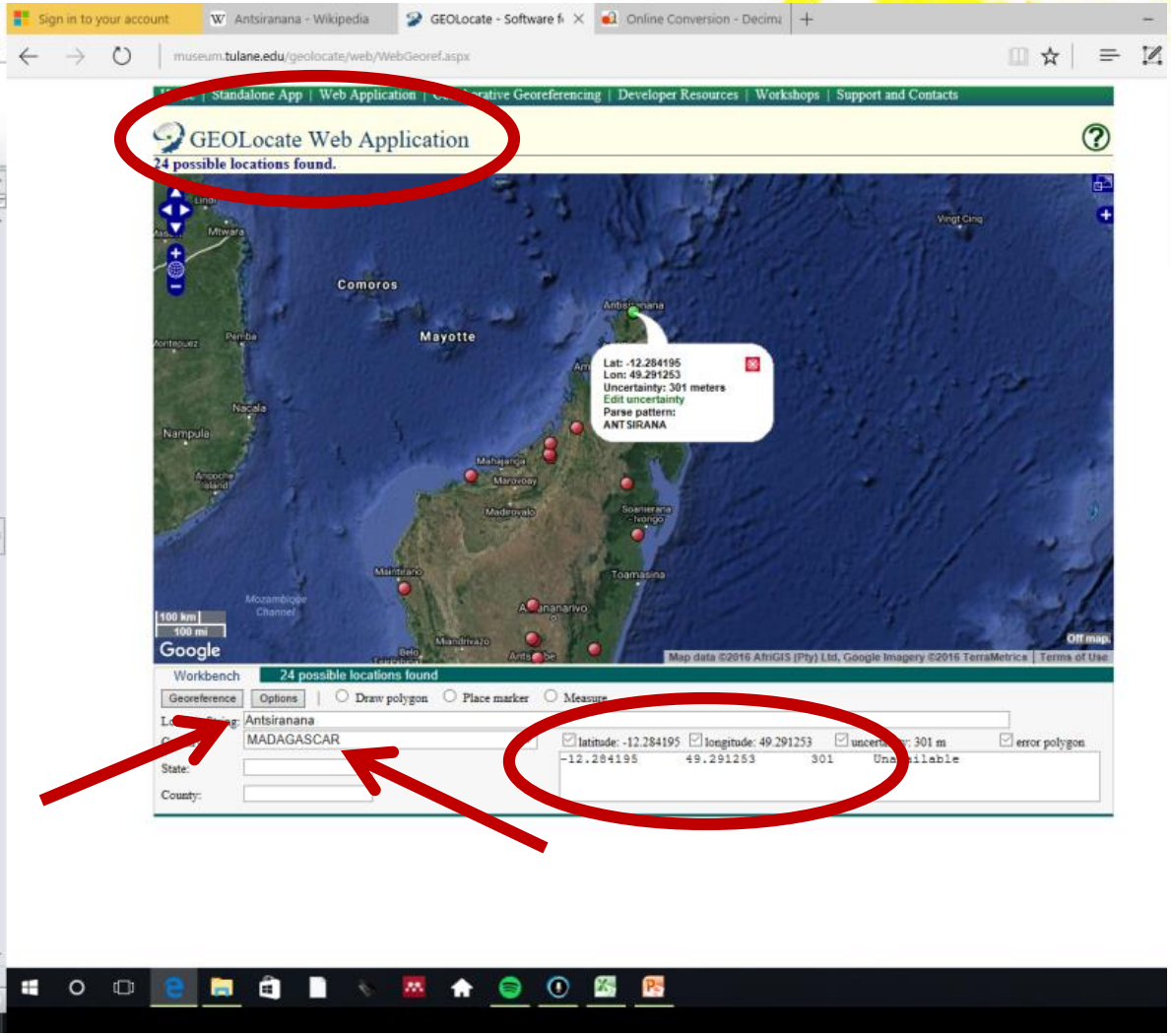
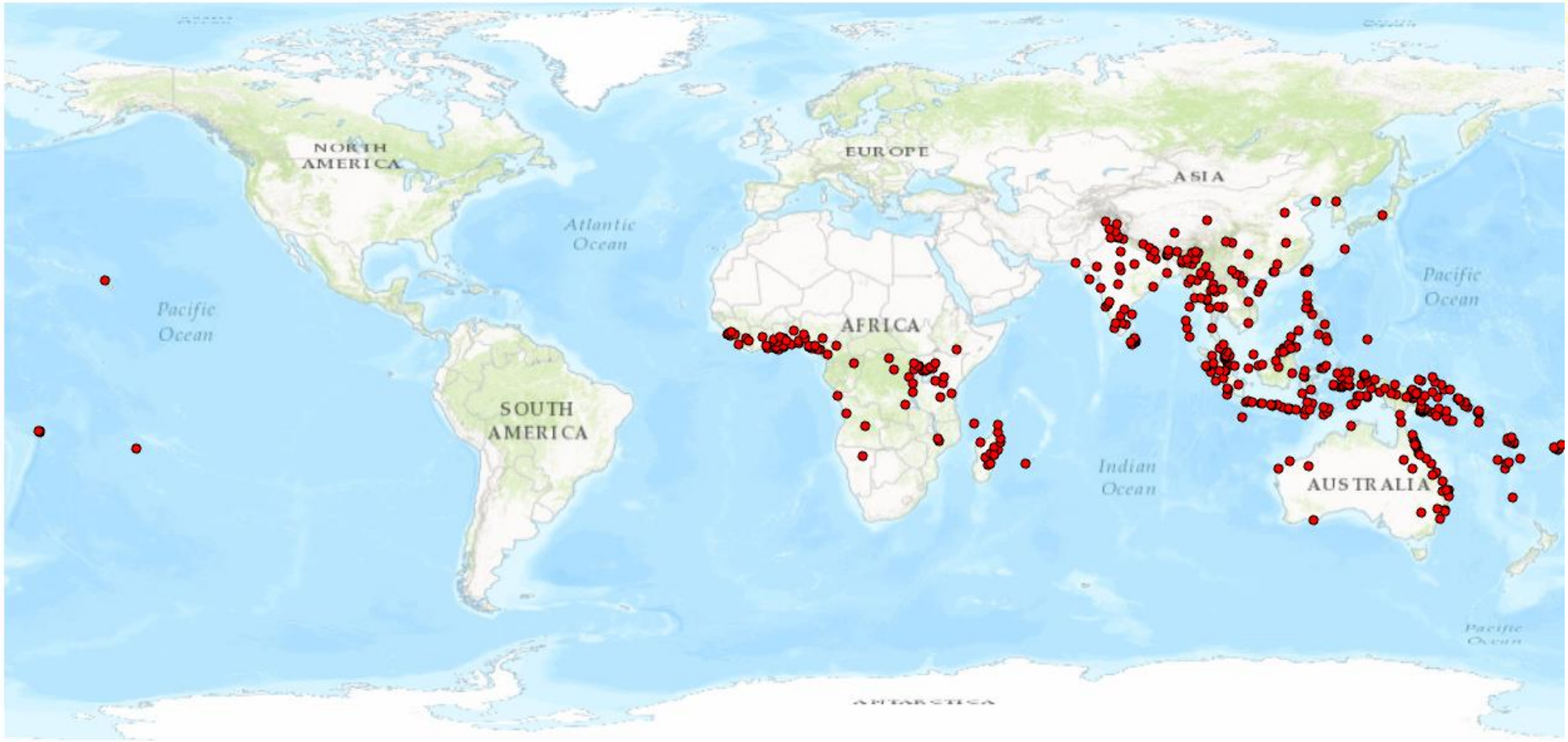


E. phalonia Range Map



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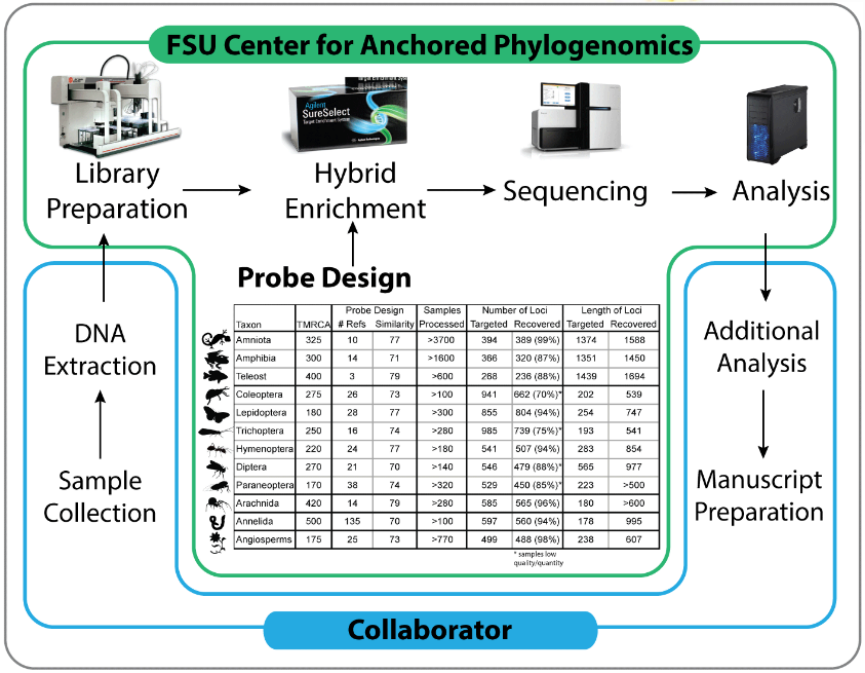
Molecular phylogeny using next-generation sequencing techniques

- Recently collected *E. phalonia* tissues from across the range obtained from fieldwork, collaborators, and private collection of Vernon Brou Jr.
- DNA extractions performed using Qiagen DNeasy kits



Taxon	TMRCA	Probe Design # Refs	Probe Design Similarity	Samples Processed	Number of Loci Targeted	Number of Loci Recovered	Length of Loci Targeted	Length of Loci Recovered
Amniota	325	10	77	>3700	394	389 (99%)	1374	1588
Amphibia	300	14	71	>1600	366	320 (87%)	1351	1450
Teleost	400	3	79	>600	268	236 (88%)	1439	1694
Coleoptera	275	26	73	>100	941	662 (70%)*	202	539
Lepidoptera	180	28	77	>300	855	804 (94%)	254	747
Trichoptera	250	16	74	>280	985	739 (75%)*	193	541
Hymenoptera	220	24	77	>180	541	507 (94%)	283	854
Diptera	270	21	70	>140	546	479 (88%)*	565	977
Paraneoptera	170	38	74	>320	529	450 (85%)*	223	>500
Arachnida	420	14	79	>280	585	565 (96%)	180	>600
Annelida	500	135	70	>100	597	560 (94%)	178	995
Angiosperms	175	25	73	>770	499	488 (98%)	238	607

* samples low quality/quantity

Courtesy of anchoredphylogeny.com

Molecular phylogeny using next-generation sequencing techniques

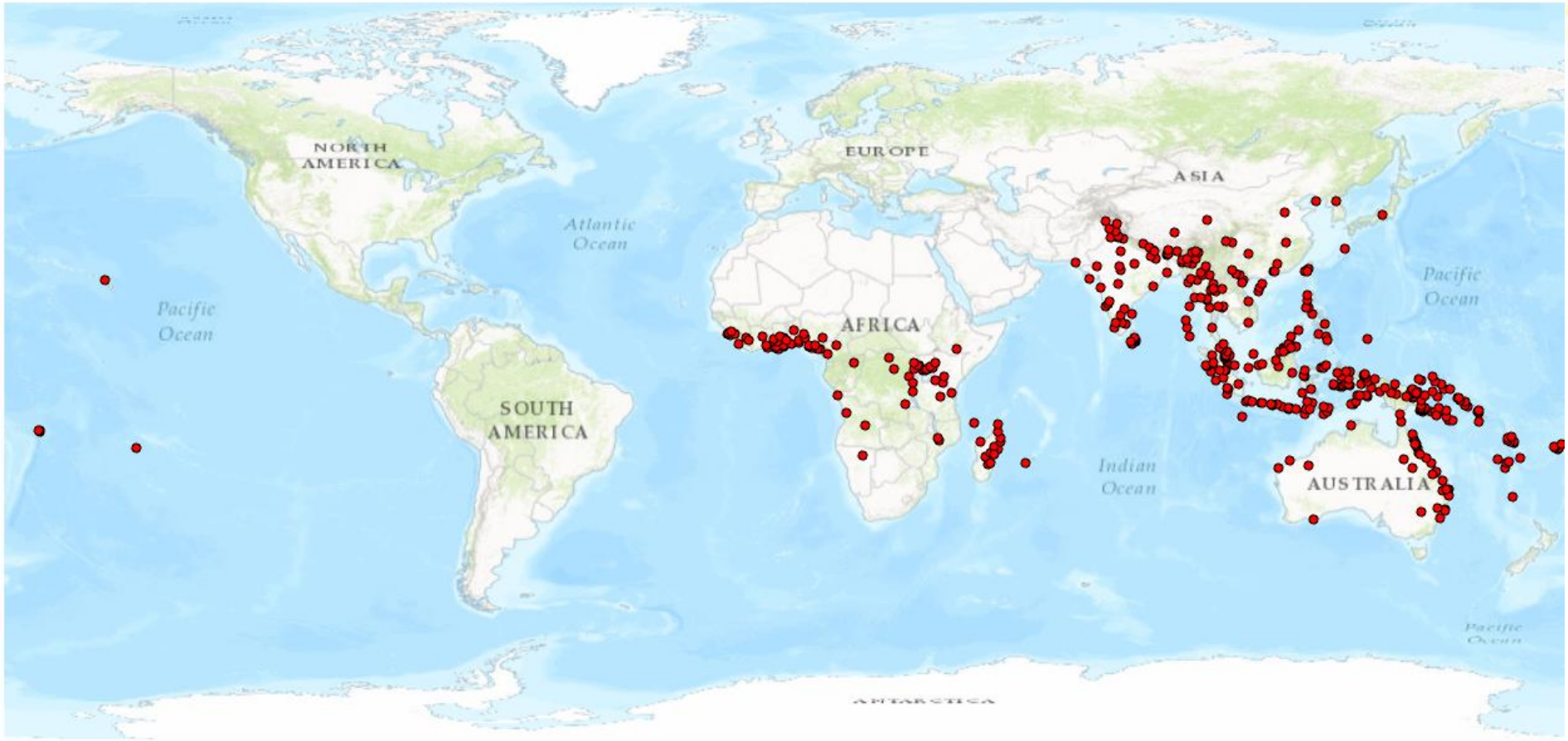
- Purified genomic DNA sent to Center for Anchored Phylogenomics at Florida State University (Lemmon et al. 2012)
- Nested probe design for Erebid moths utilized (Zaspel et al. in prep)
  - Shallow and deep level phylogenetic questions
  - Approximately 200 informative anonymous nuclear loci (ANL) will be sampled for up to 60 terminals

- Maximum likelihood tree constructed using RAxML (Stamatakis 2014) through the CIPRES portal (Miller et al. 2015)
- Tree support assessed using bootstrapping

Klem et al. in prep

E. okurai image courtesy of Taiwan biodiversity Information Facility

E. phalonia Range Map



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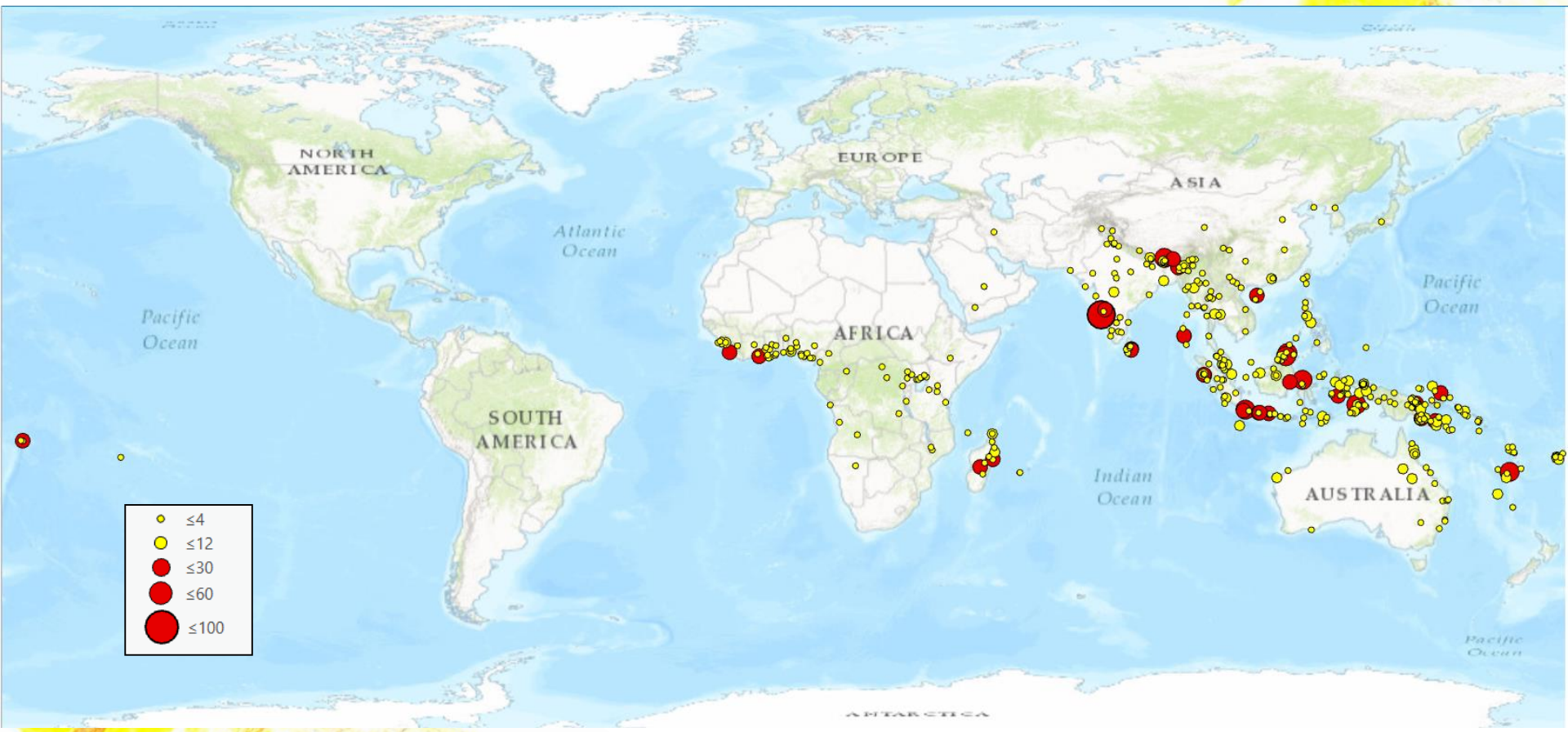
Range Symbolized by Specimen Occurrence



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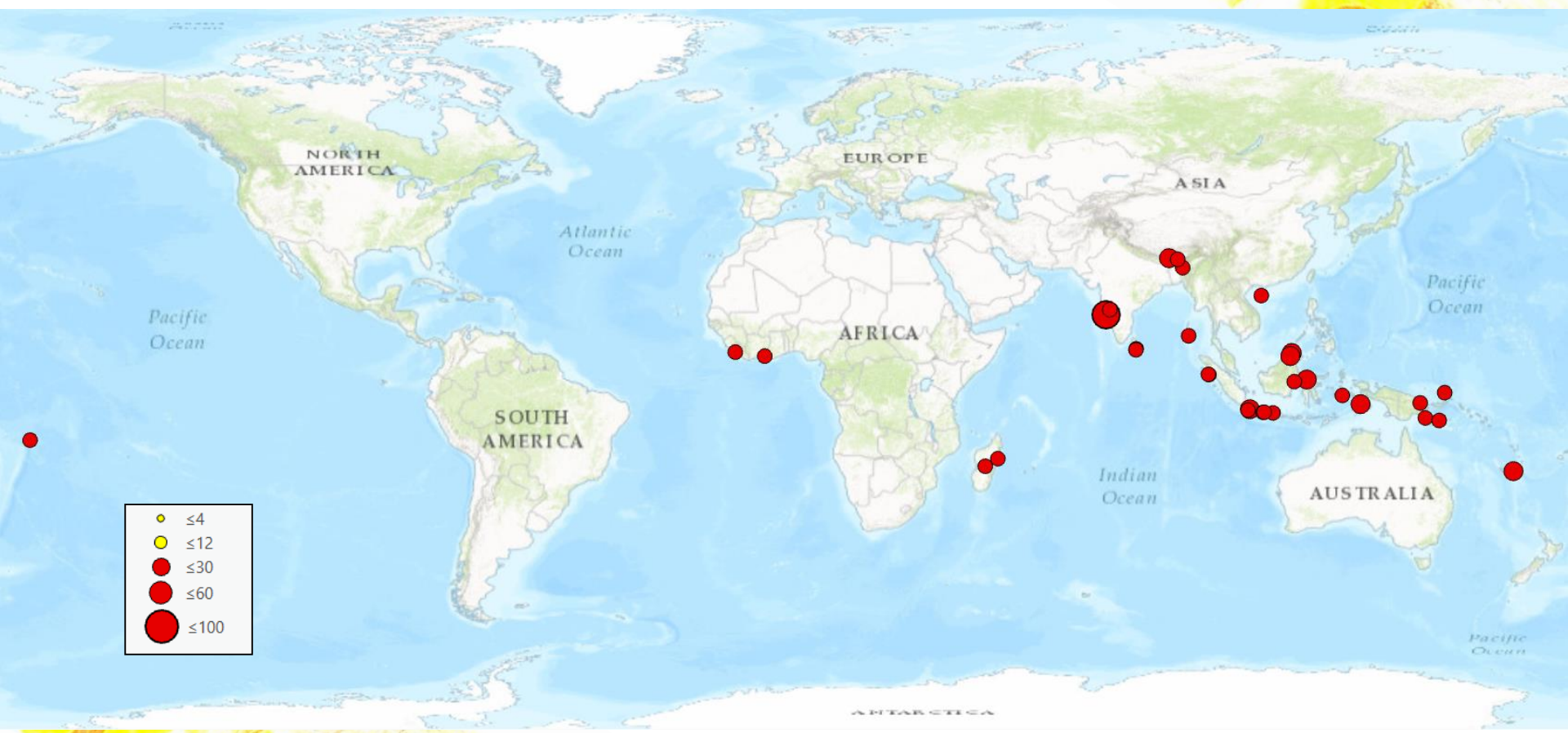

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Next Steps

- Build a MaxEnt model
  - Climatic variables from WorldClim
- Use co-occurrence data from closely related species *E. lequeuxi*, *E. oliveri*, and *E. steppingstonia* to construct a joint species distribution model (JSDM) to evaluate niche overlap and competition (Clark et al. 2014)
  - Could also be used to test competition or exclusion between related clades from molecular phylogeny

Acknowledgements

- 2016 Zaspel Lab
- Purdue Entomology
- Vernon Brou Jr.
- Matthew Siderhurst
- Natural History Museum, London (NHM)
  - Alessandro Giusti
  - David Lees
  - Geoff Martin
- Florida Museum of Natural History (FLMNH)
- United States National Museum of Natural History (USNMNH)
- Purdue Entomological Research Collection (PERC)

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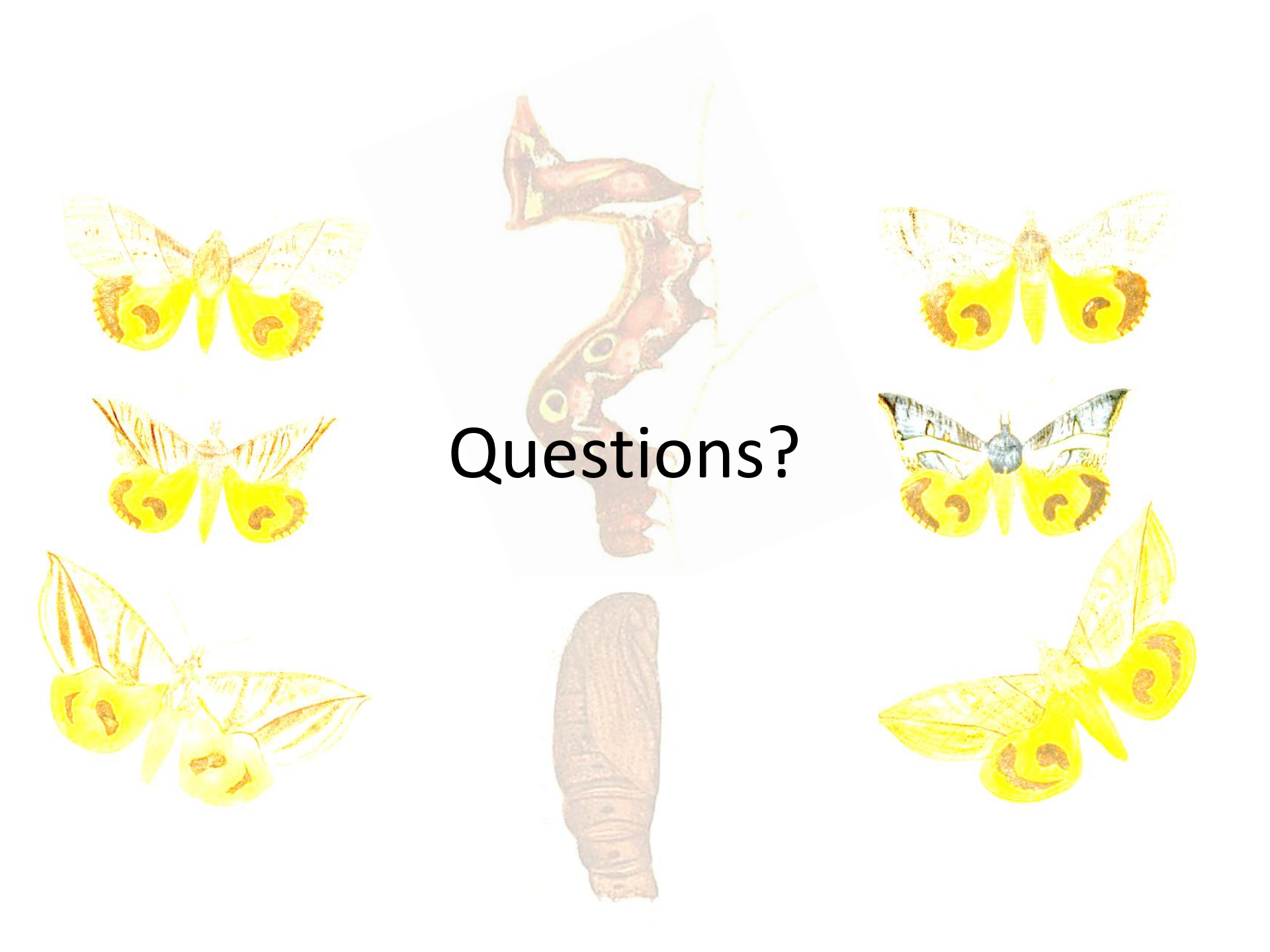
Questions?