St. Lucia in a world of beetles and other insects

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research: evolutionary biology, insects, islands, biogeography

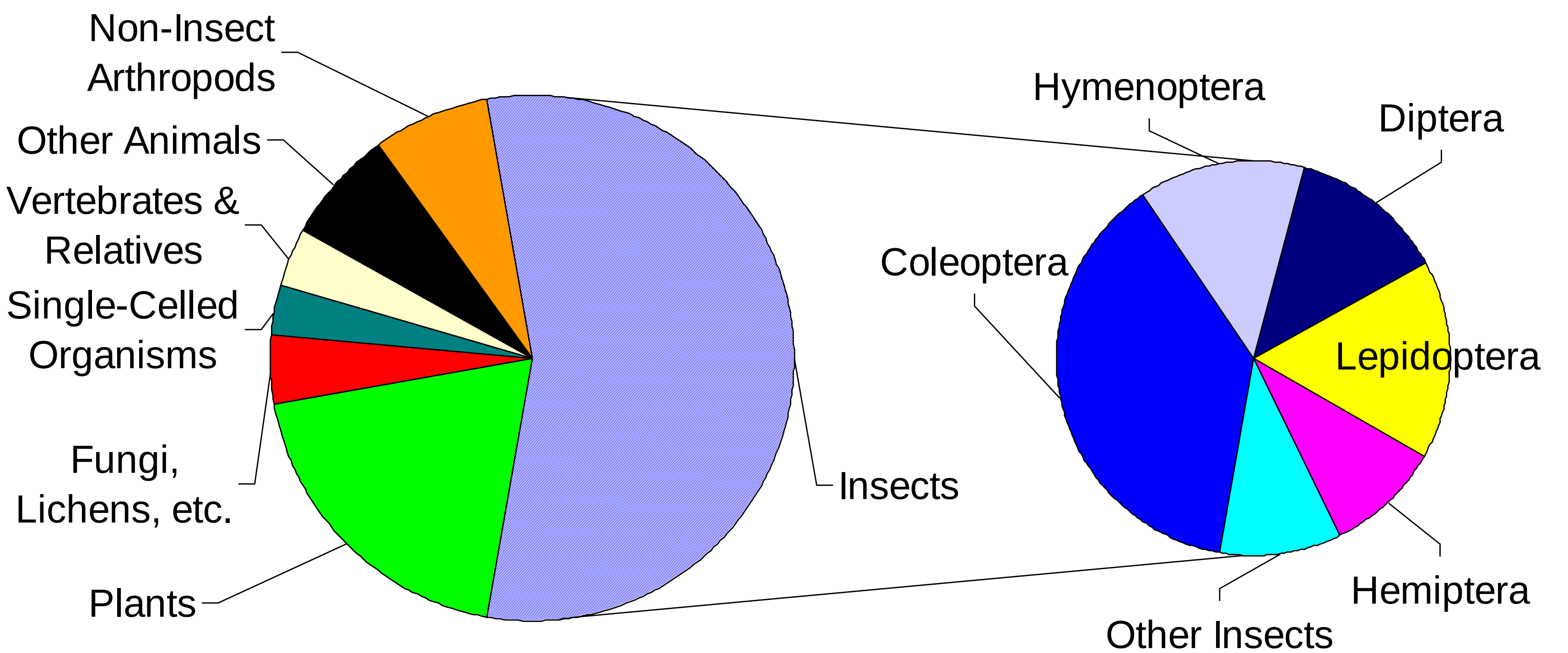
topics

An introduction to or review of topics on:

1. insect diversity;   and the good, bad, and ugly
2. beetle diversity
3. the Caribbean biodiversity hot spot
4. known beetle diversity in the Lesser Antilles
5. the Montserrat project and results - background

6. the St. Lucia beetle project and expectations (predictions)

How abundant are insect species? All life is about 1,500,000 species
The overwhelming diversity of insects and beetles in the world of living things.



a total of some 1,500,000 species of life

Fig. 1. **Relative Biodiversity of Described Organisms** (Data from Chapman 2006).
So, <u>why</u> are insects and beetles so diverse?

Start with insects: why are insects so diverse?

Diverse in nature: but why so many? The answer must lie in some properties or characteristics that they have. Possible ones for our consideration are:

1. Exoskeleton. Made of tough but lightweight chitin.

2. **Body.** Segmentally arranged as **serially repeating** units, but with **specialized** regions - serial homology.

3. Many segments have **jointed appendages** - repeated and each appendage and segment available for specialization.

4. **Plasticity** of body regions and appendages (leg adaptations), the same basic structure adapts to many functions.

5. **Small size**. There are ecological consequences of finely dividing ecosystems– can use smaller resource units, can be inconspicuous, etc. . But, there are also drawbacks (physiological consequences of large surface area /volume ratio, the water loss problem).

6. **<u>FLIGHT</u>**. 95% of all insect species are winged – for escape, for efficiency in resource finding and exploitation, mate finding, etc.

7. **<u>Metamorphosis</u>**. 85% of all insect species have "complete metamorphosis" – 4 discrete life-cycle stages. Egg, larva, pupa, adult. The consequence is to more finely divide habitats and resources. <u>Larvae</u> can act as <u>ecologically different species</u>.

8. **<u>Fecundity</u>**. It is legendary. The old story: if 1 female *Drosophila* produces 100 eggs, and if all survive, and if there are 25 generations per year (100^{25}/year), and if are there are 1000 flies /inch ^{3} ; then the reproductive output is a ball 96x10 ^{6} miles in diameter.

This fecundity allows for **quick adaptation** in response to selective pressures, such as the immunity developed against insecticides, as one example. =Abundance

9. Various levels of social development – **<u>sociality</u>** – colonies of social insects are very successful.

All this makes them successful, diverse, and important in nature.

Important in nature! To us?
The bad, the good, (and the ugly ?): a review

The <u>bad</u>: from a human viewpoint, what people are most interested in.

I. Insect pests;

- **A. Plant pests**
  1. **of field crops**
  2. **of truck crops and gardens**
  3. **greenhouses**
  4. **fruit crops**
  5. **shade and forest trees**
  6. **carriers of plant disease**
  7. **stored food and stored product pests**
- **B. Pests of humans and animals**
  1. **of habitations: cockroaches and termites**
  2. **parasites of humans and animals (warble flies)**
  3. **stings and allergies**
  4. **carriers of disease organisms**

Really only a <u>very few in total</u>: maybe less than 1000 species worldwide are really serious

The good (strictly a human viewpoint – a value judgement)

II. The Good: helpful insects, for biocontrol of pests, etc.

A. Predators.

A. coccinellid lady bird beetles prey on aphids and scale insects

B. carabid beetles are general predators in fields and orchards

3. other beetles, such as staphylinid rove beetles

4. dragonflies as predators on mosquito adults and larvae

5. preying mantids (Mantodea)

6. lacewings (Neuroptera) prey on aphids, etc.

7. ambush and assassin bugs (Hemiptera) as predators in fields

8. many fly larvae (Diptera; Tabanidae) are predators

9. vespid wasps (Hymenoptera) are predators on moth larvae

B. Parasites and parasitoids

1. braconids and ichneumonid larvae (Hymenoptera) in insect larvae

2. fly larvae, especially tachinids, in insect larvae

The good continued.

C. Herbivores; for weed control: many examples, a few are:

1. Cactoblastis moth control of prickley pear cactus in Australia
2. chrysomelid leaf beetles control St. John's wort in CA & Aust.
3. tephritid fruit flies control Eupatorium in Hawaii
4. weevils control water hyacinth in Florida
5. many more

D. Pollination; honey bees etc.

E. Make useful products: honey, wax, shellac, cochineel dye, etc.

F. As human food; especially Asia and Africa

G. Recreational (freshwater fishing) and aesthetic values (butterflies)

H. Scientific study: genetics, physiology, etc.

I. Human health: dung beetles destroying eggs of parasitic worms of humans and livestock

All the above number in tens of thousands of species of "use" to humans.

The rest?

- The <u>rest</u>: some 750,000 species?

- **III. <u>Neutral</u> insects (neutral from a human perspective).**

    Ecosystem health: water cleansing, decompositon of wastes (such as dung) and removal of sites of disease infection, nutrient recycling, etc.

    The “balance of nature”

- **But it is most species: hundreds of thousands of insect species. “Neighbors” with whom we share the planet.**

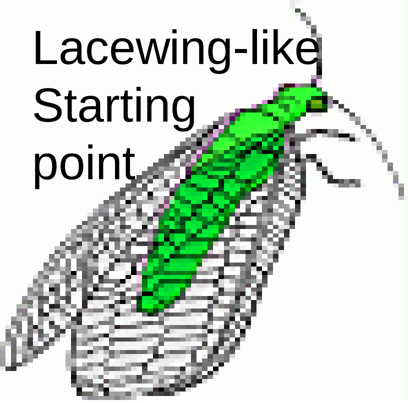
- **Are <u>these</u> of any importance?**

Starting with a premise that humans have been important in changing the planet:

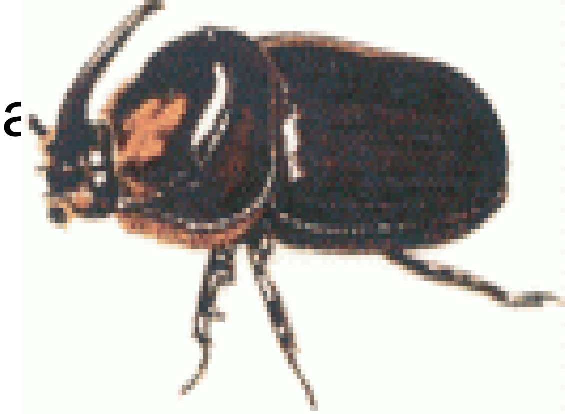
(consider how St. Lucia has been changed in 400 years).

- "If all mankind were to disappear tomorrow, the world would regenerate back into the rich state of equilibrium that existed 10,000 years ago. If insects were to vanish, the terrestrial environment would collapse into chaos."
  - » E. O. Wilson, Omni, Sept. 1990.

- Now, why beetles? Why are they so diverse and successful? What defines a beetle: its properties?



How to “make” a



From a holometabolous (endopterygote) ancestor (havIng a pupal stage), something like a lacewing; disconnecting larva from adult

<u>Neuroptera (ancestral) properties</u>	→	<u>Beetle properties</u>
Body elongate		Body more compact
Exoskeleton thin and soft		Exoskeleton thick and tough
Front wings membranous		Front wings thickened (elytra)
Front wings loose at sides		Elytra fit snugly to body sides
Front & hind wings used in flight		Elytra not used in flight only hind wings used to fly
Hind wings longer than body		Hind wings folded under elytra - protected from tearing

All this anatomical change gives the resulting features

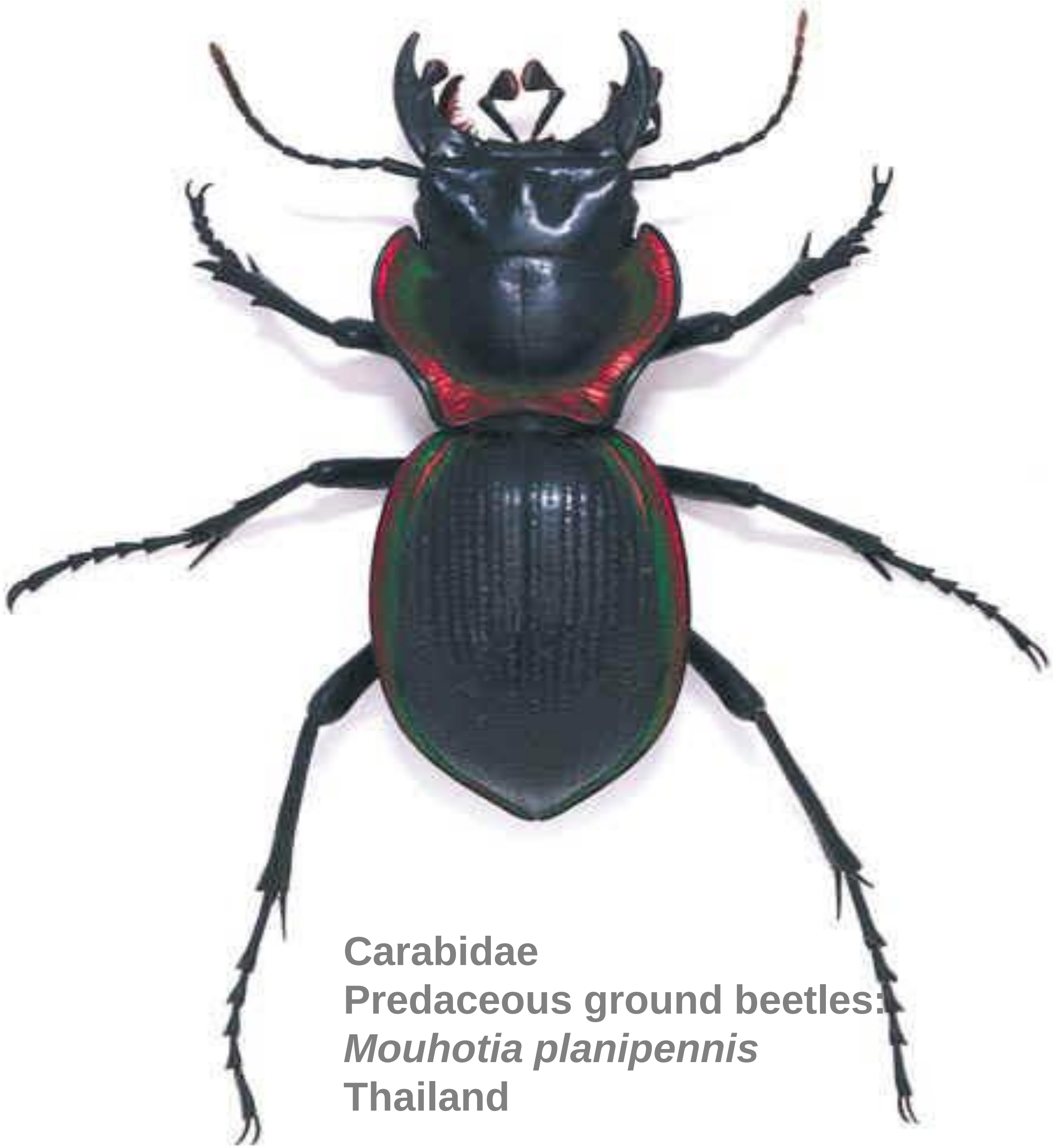
All this gives the resulting beetle features:

1. Armored body
   a. More resistant to predation
   b. More resistant to abrasion and wing tearing; thus able to dig and hide in soil; in wood; under bark; under rocks; etc.
2. Spiracles (entrances to respiratory system) of abdomen sealed inside and under edges of elytra.
   a. water cannot get in: can move to aquatic habitats
   b. water vapor cannot get out – water conservation: can move to arid habitats

All these features let beetles live everywhere (but not ocean) and do everything – a wider range of niches are filled by beetles than any other group of animals: thus their diversity

Larvae can live in very different places and do very different things than the adults: ecologically acting as two separate species – more diversity.

Lets review some interesting beetles.



Carabidae
Predaceous ground beetles:
Mouhotia planipennis
Thailand

Carabidae;
Predaceous ground beetles:
Seedcorn beetle

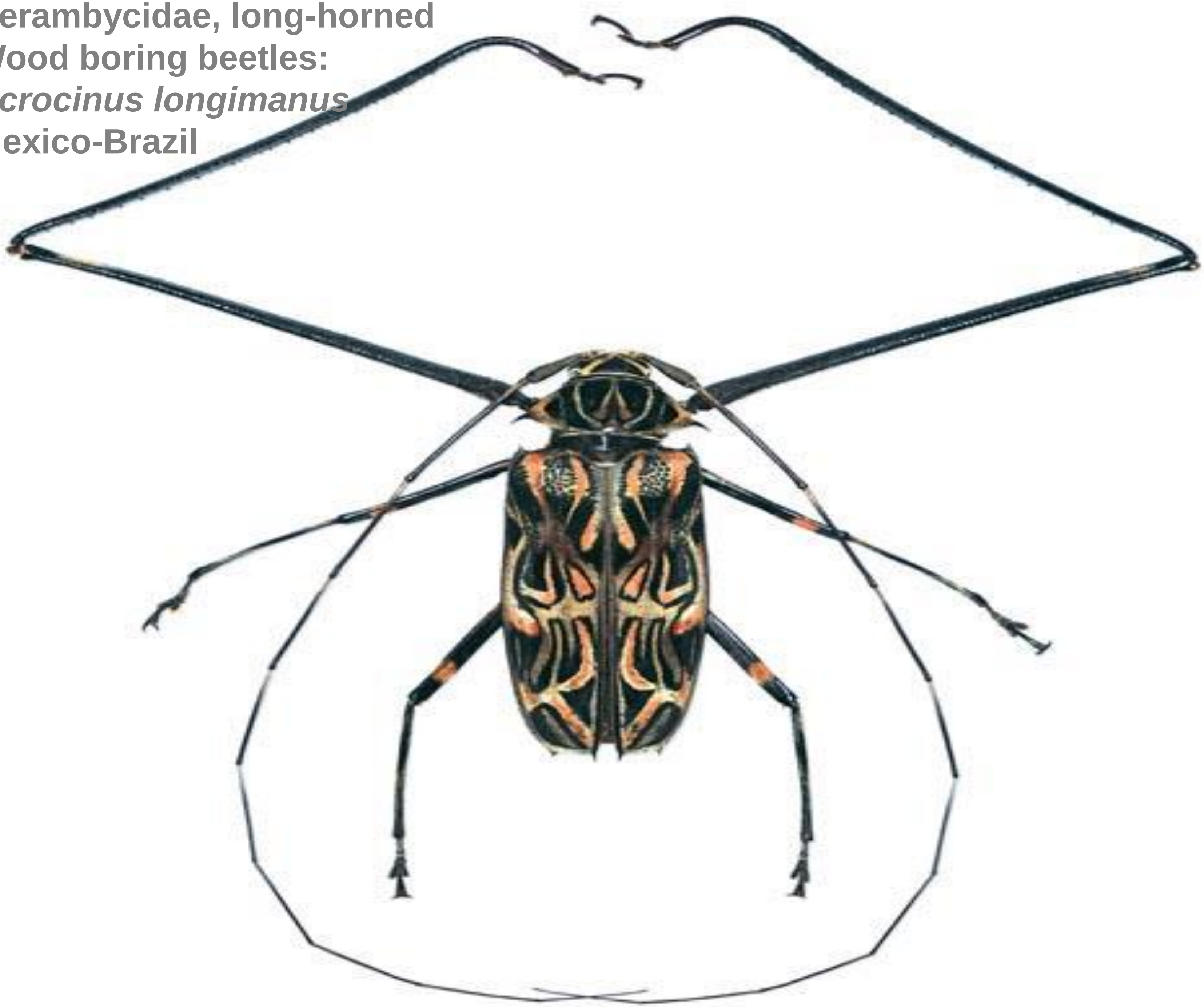
Dytiscidae;
Predaceous water beetles

Meloidae, blister beetles

Lampyridae, fire flies

Elateridae, click beetles

Cerambycidae, long-horned Wood boring beetles:
Acrocinus longimanus
Mexico-Brazil

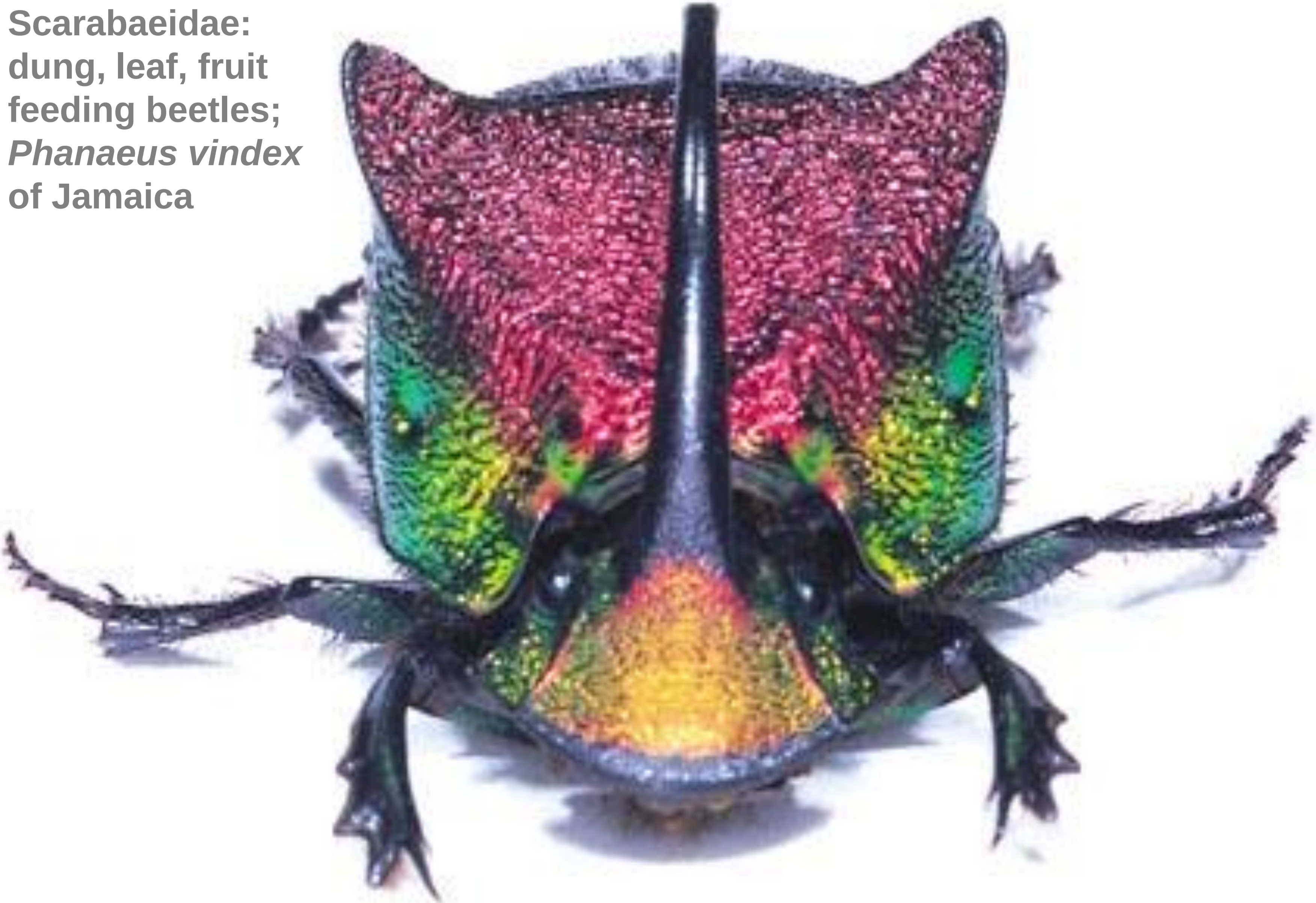


Buprestidae
Metallic wood-boring
Beetles; Euchroma gigantea
Mexico-Bolivia, Caribbean

Scarabaeidae;
Fruit chafer


Scarabaeidae;
Japanese beetle,
introduced
defoliator in
USA & Canada

Scarabaeidae: dung, leaf, fruit feeding beetles; *Phanaeus vindex* of Jamaica



Tenebrionidae
Darkling beetles:
Tribolium confusum
Confused flour beetle, stored products pest

Coccinellidae;
Lady beetles;
12 spotted lady beetle

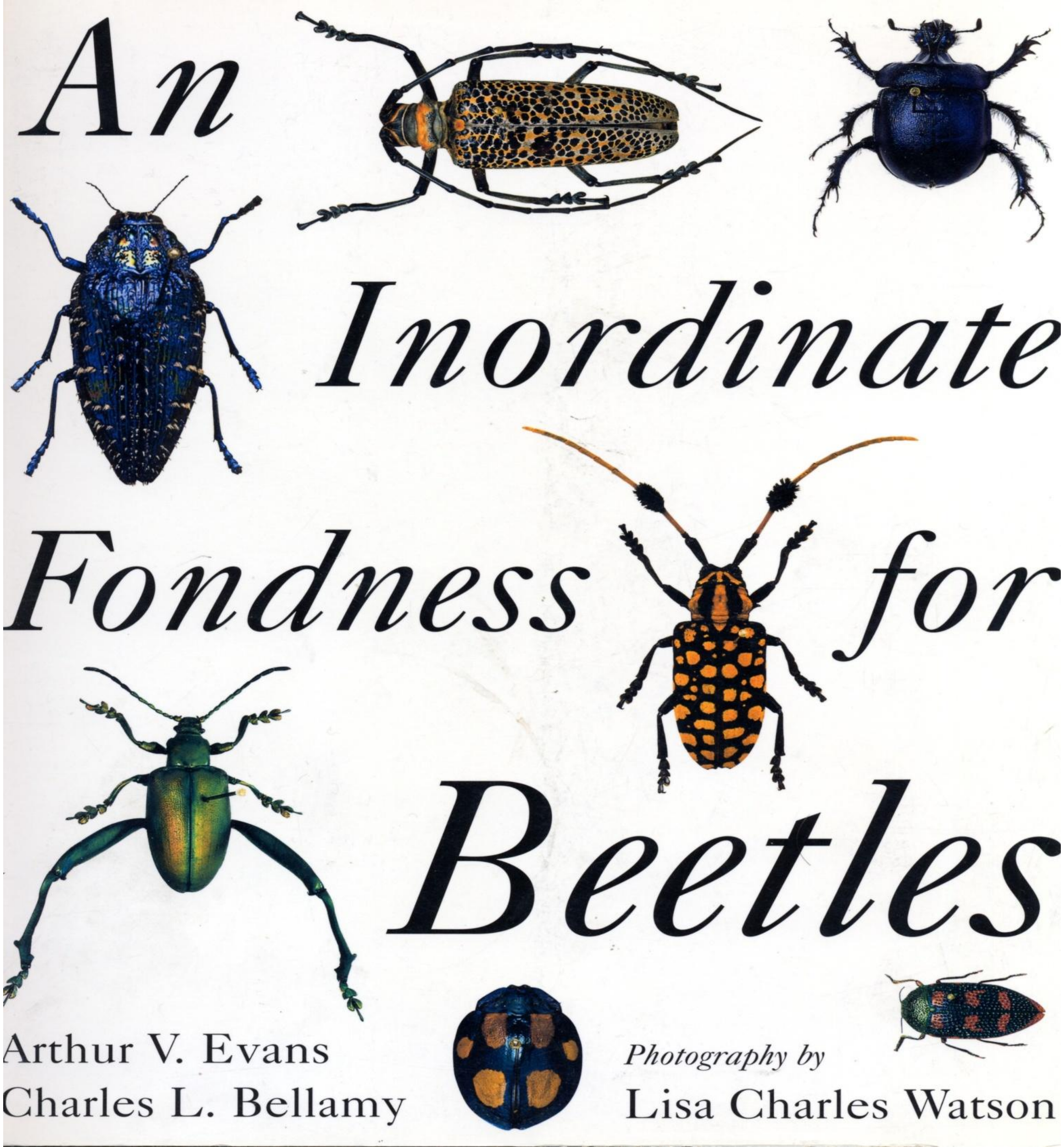
Chrysomelidae;
Leaf-feeding beetles:
Bean leaf beetles
Red and yellow phases

Chrysomelidae
Alfalfa flea beetle;
Found in alfalfa fields

Chrysomelidae;
Leaf-feeding beetles;
Southern corn rootworm, or
Spotted cucmber beetle

Curculionidae:
Long-horned weevils
Imported for weed control

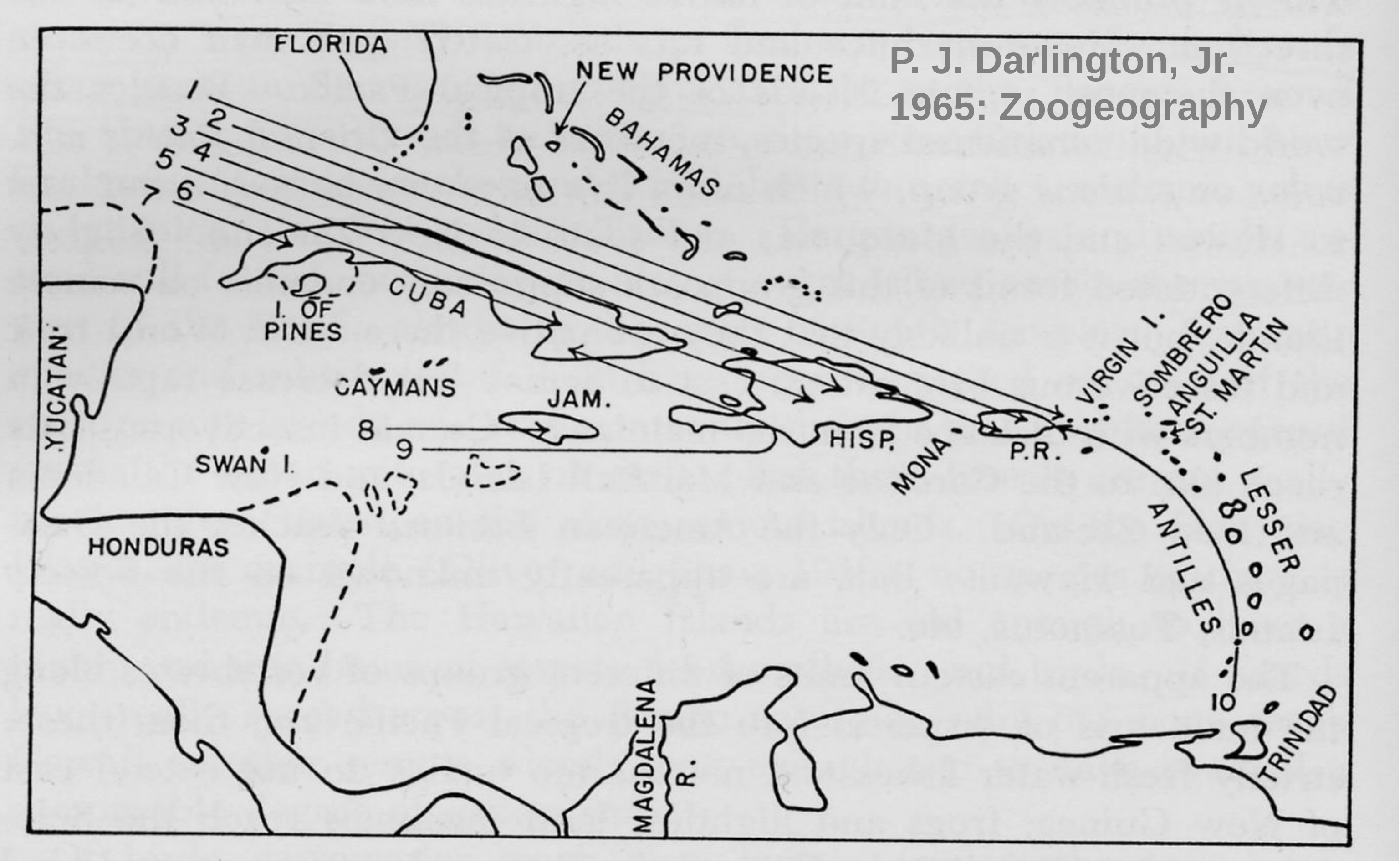

Curculionidae
Alfalfa weevil
J. BRADSHAW


An Inordinate Fondness for Beetles
Arthur V. Evans
Charles L. Bellamy
Photography by
Lisa Charles Watson

West Indian beetles: how did they get here?

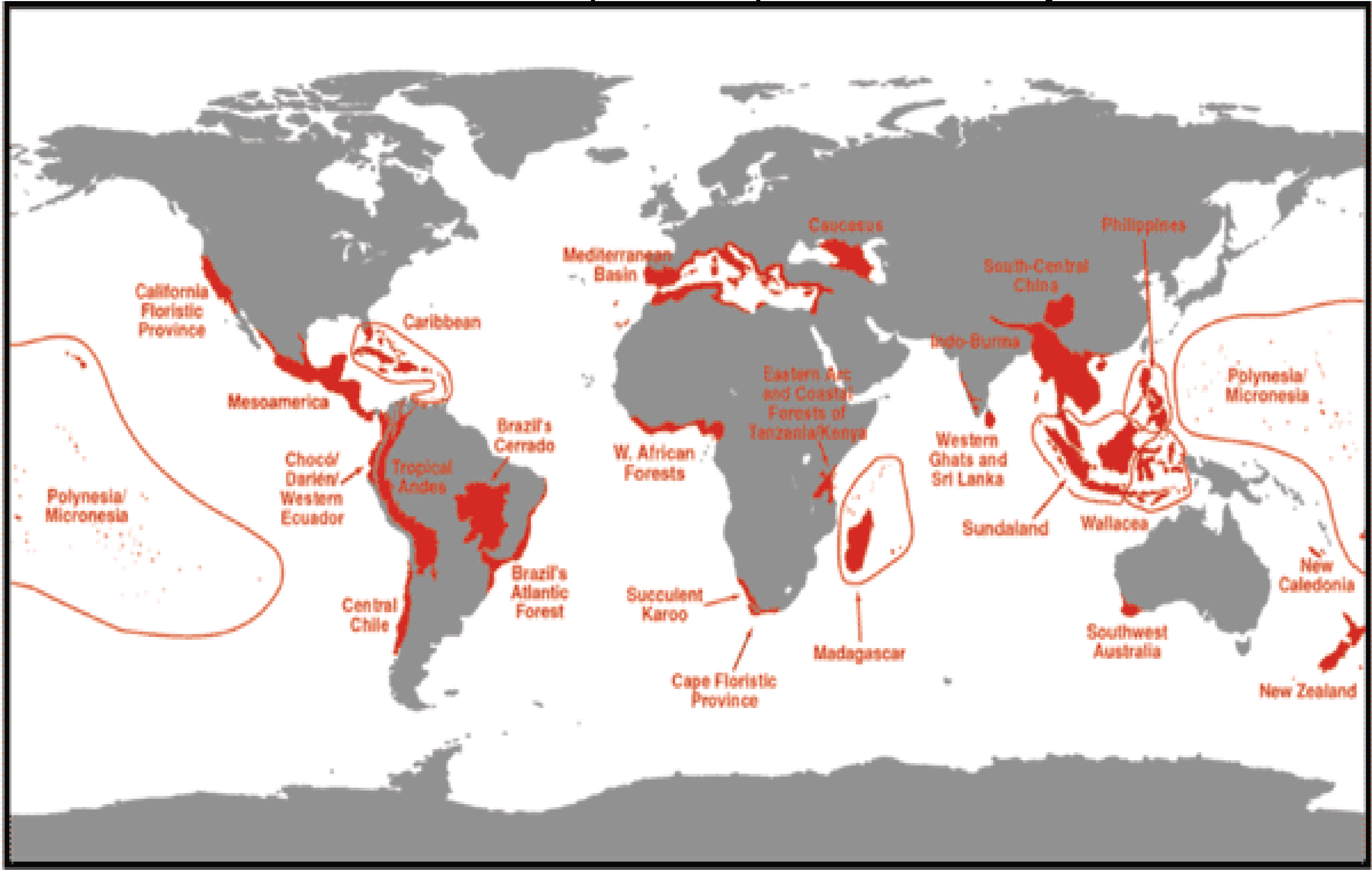
categories of geographical distributions:

1. Introduced: by accident or intention
2. Naturally dispersed from elsewhere



3. Endemic - evolved here from earlier ancestor: the most special group

But, let's step back: Lesser Antilles are part of Caribbean "hotspot" of species diversity



Myers et al. 2000; Nature vol. 400: 853-858

The Caribbean biodiversity "hotspot."

Table 3 Leading hotspots in terms of endemics

Hotspot	Endemic plants (% of global total, 300,000)	Endemic vertebrates (% of global total, 27,298)
Tropical Andes*	20,000 (6.7)	1,567 (5.7)
Sundaland*	15,000 (5.0)	701 (2.6)
Madagascar*	9,704 (3.2)	771 (2.8)
Brazil's Atlantic Forest*	8,000 (2.7)	567 (2.1)
Caribbean*	7,000 (2.3)	779 (2.9)
Sub-totals (% rounded)	59,704 (19.9)	4,385 (16.1)
Mesoamerica	5,000 (1.7)	1,159 (4.2)
Mediterranean Basin	13,000 (4.3)	235 (0.9)
Indo-Burma	7,000 (2.3)	528 (1.9)
Philippines	5,832 (1.9)	519 (1.9)
Totals	90,536 (30.1)†	6,826 (25.0)

* Hotspots with at least 2% of the world's endemic plants and vertebrates, and comprising only 0.4% of the Earth's land surface (all nine amount to 0.7% of the Earth's land surface).
† This would total 30.2% but for rounding of numbers in the individual hotspots.

Myers et al. 2000; Nature vol. 400: 853-858

Table 4 Species/area ratios per 100 km^2 of hotspots

Hotspot	Endemic plants	Endemic vertebrates
Tropical Andes	6.4	0.5
Mesoamerica	2.2	0.5
Caribbean	23.5	2.6
Brazil's Atlantic Forest	8.7	0.6
Choco/Darien/Western Ecuador	3.6	0.7
Brazil's Cerrado	1.2	0.03
Central Chile	1.8	0.06
California Floristic Province	2.7	0.09
Madagascar	16.4	1.3
Eastern Arc and Coastal Forests of Tanzania/Kenya	75	6.1
Western African Forests	1.8	0.2
Cape Floristic Province	31.6	0.3
Succulent Karoo	6.5	0.15
Mediterranean Basin	11.8	0.2
Caucasus	3.2	0.1
Sundaland	12.0	0.6
Wallacea	2.9	1.0
Philippines	64.7	5.7
Indo-Burma	7.0	0.5
South-Central China	5.5	0.3
Western Ghats/Sri Lanka	17.5	2.9
SW Australia	13.0	0.3
New Caledonia	49.1	1.6
New Zealand	3.1	0.2
Polynesia/Micronesia	33.3	2.2

Caribbean Islands

Diversity and endemism

(Conservation International: www.biodiversityhotspots.org)

Taxonomic Group	Species	Endemic Species	Percent Endemism
Plants	13,000	6,550	50
Mammals	89	41	46
Birds	607	167	28
Reptiles	499	468	94
Amphibians	164	165	100
Freshwater Fishes	161	65	40

Conclusions:

Caribbean islands have <u>many</u> species per unit of land area.

They are well known for plant species; vertebrate species; butterflies; dragonflies. The <u>rest is poorly known.</u>

Now, what about St. Lucia? How many beetles are here?

We do <u>not</u> know!

That's why I am here. To help find out with a long-term research project, called:

<u>The beetles of the Lesser Antilles: diversity, distribution, and biogeography.</u>

The project is scheduled to go at least 5 (hopefully more) years; and will focus on the "high" islands of the southern end of the Lesser Antilles. Research support from Natural Sciences and Englineering Research Council of Canada (NSERC).

Composed of literature search, field work, lab and museum work on identifying what is caught; and then putting it all together to see <u>what it means</u>.

At its simplest: this can be a contribution to a summary of what is here. Perhaps it can have some applied, or management, or conservation value.

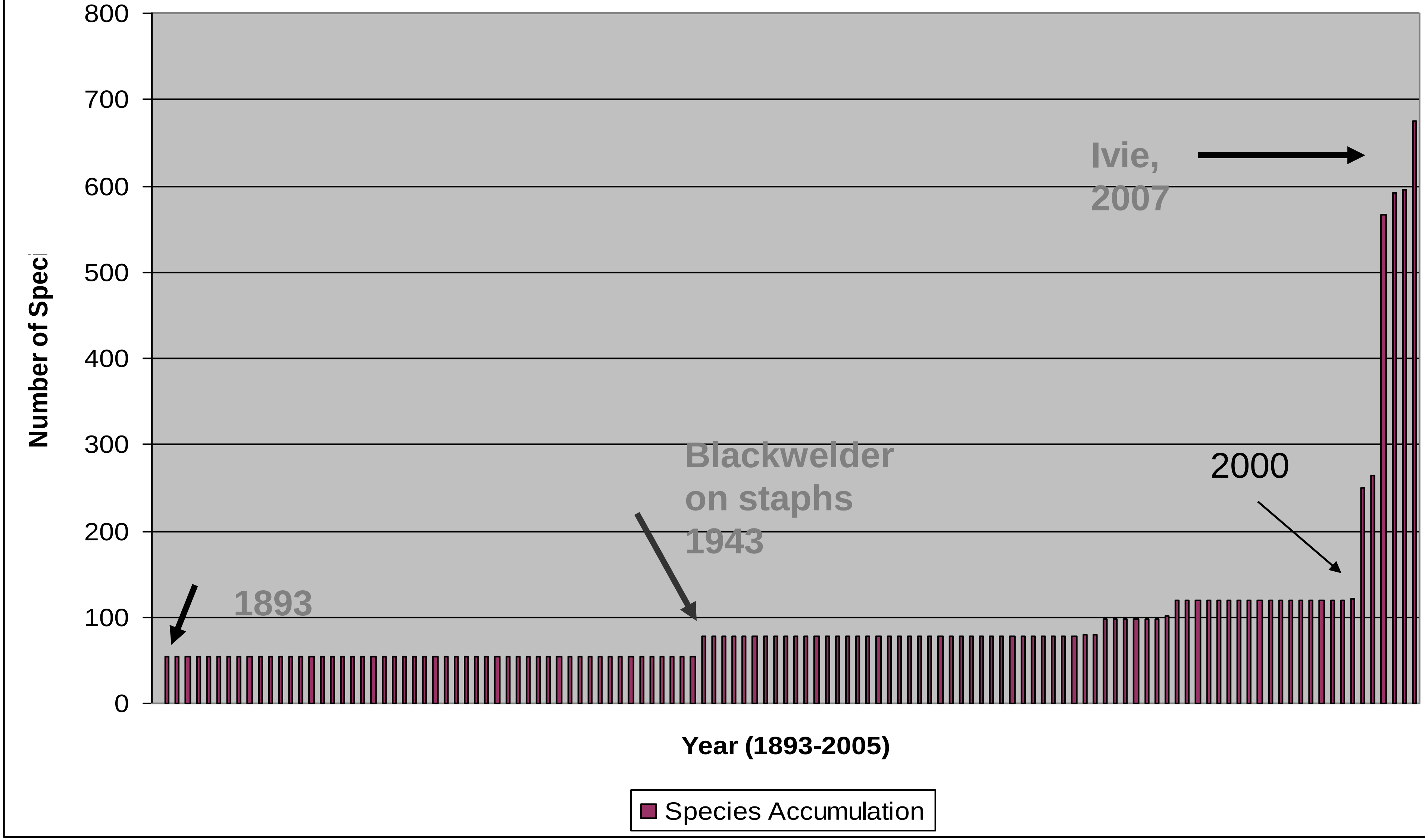
So, What do we know right now?

Land masses	*area*	*known beetle species (ex. literature)*
Greater Antilles		
Cuba	**111,000 km^2**	**2673, Peck 2005**
Hispaniola	**76,000 km^2**	**1700, Perez 2007**
Puerto Rico & Virgins	**?**	**?**
Jamaica, Caymans, etc	**?**	**?**
***Lesser Antilles:* many northern smaller, drier, low islands**		
The following southern "high" wetter islands should be most diverse		
Montserrat**	**104 km^2**	**726+, Ivie 2007, 827+ projected**
– Guadeloupe group	**1693 km^2**	**710+, Leng & Mutchler 1917**
– Dominica	**751 km^2**	**361, Peck 2006a**
– Martinique	**1100 km^2**	**134+**
– St. Lucia	**616 km^2**	**113+**
– St. Vincent & Grenadines	**389 km^2**	**408+**
– Barbados	**430 km^2**	**239, Bennett & Alam 1985**
– Grenada	**344 km^2**	**507, Woodruff et al. 1998 (now 644)**
Continental shelf islands and mainland		
– Tobago	**?**	**672, Peck et al 2002**
– Trinidad	**5,130 km^2**	
– South America	**?**	
Galapagos Islands	**7882 km^2**	**486, Peck 2006b**

What can we conclude

1. Higher and wetter and larger islands have more species.
2. When compared to Montserrat, most islands seem to be poorly known.
3. There is probably <u>much yet to discover</u>
4. Based on Montserrat, can we “estimate” how much remains to be discovered in other islands?

5. What makes Montserrat special, as above? How to apply it to St. Lucia? Get some background.



Accumulation of Beetle Species Discovered on Montserrat from 1893 to 2005.

The Montserrat project of Prof. M. Ivie, 2000-2006: Dept. Entomology, Univ. Montana, USA

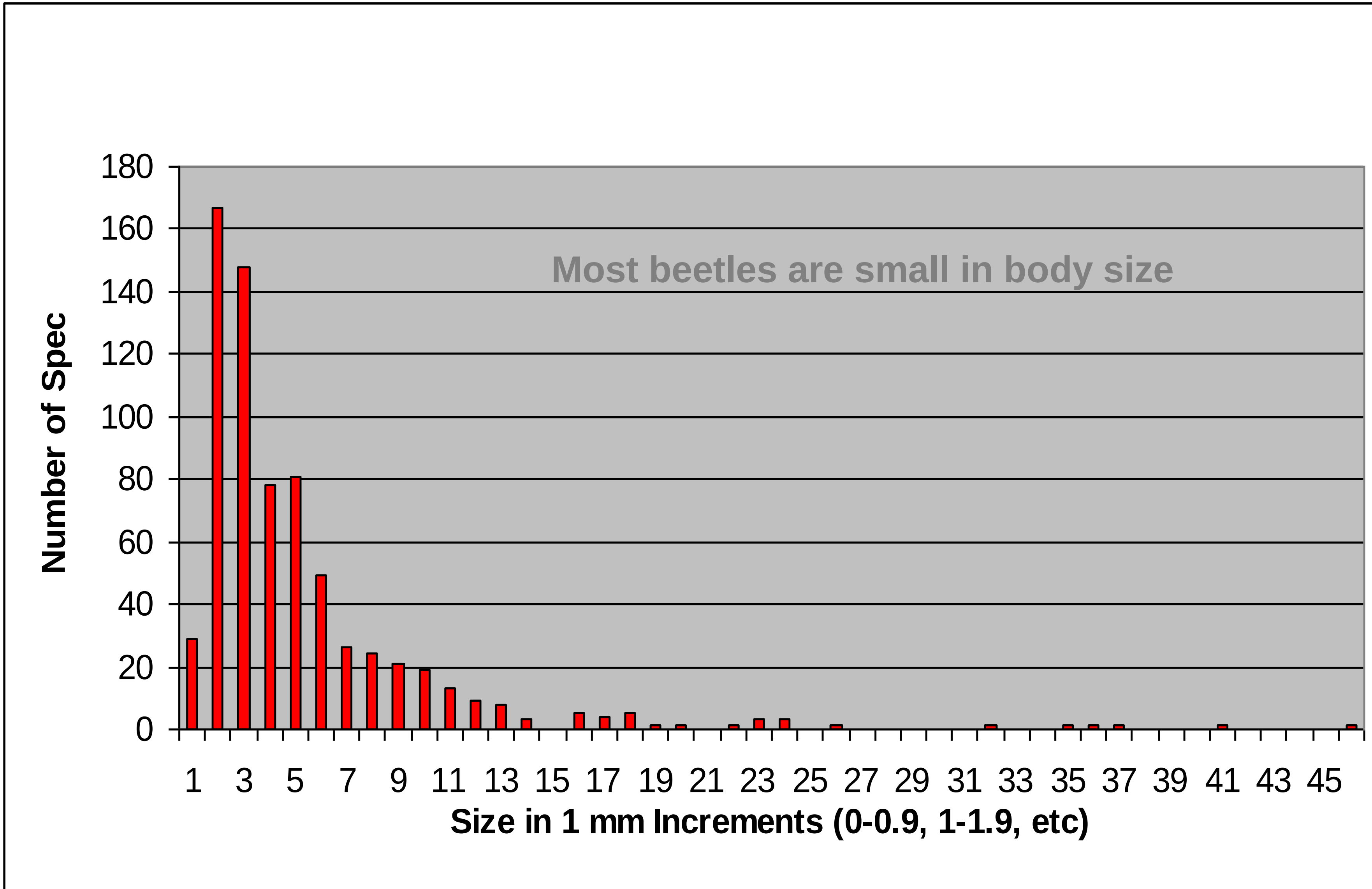
Field work began in 2000, after Soufriere eruptions in S of island

Effort: Dr. & Mrs Ivie, US students, Montserrat students, Dept Agric. Staff
several person-years of active hand collecting
several trap-years of passive trap collecting

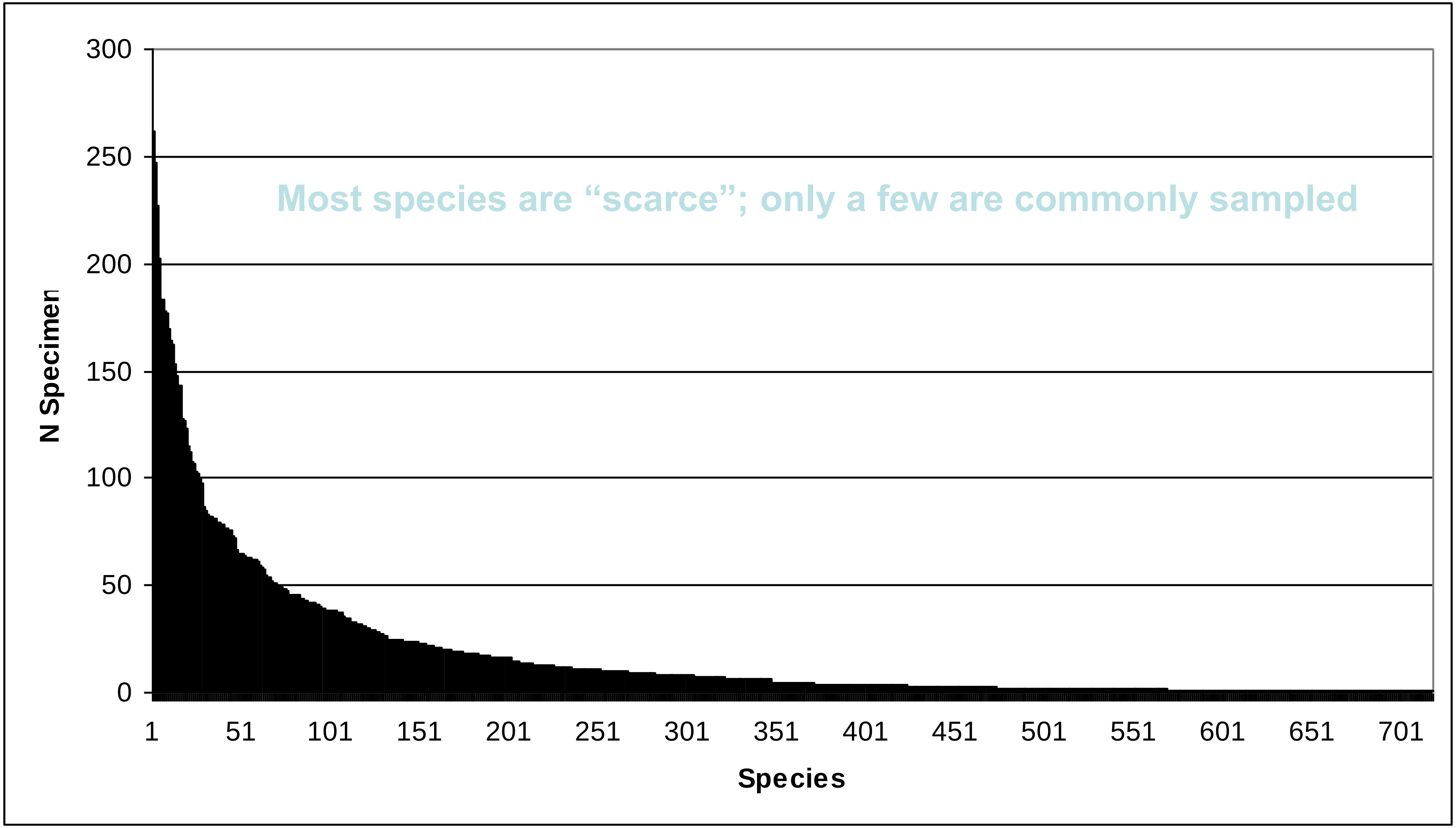
Over 1,000,000 arthropod specimens, mostly insects
13,044 beetles mounted and labeled for identification by students
thousands of hours making identifications by scientific team

Results to date:
Beetles: 718 species; in 63 of the 130 families of the world
but only 500± can be named to species
81+ single island endemics
53 introduced by humans
others naturally occurring on other islands and/or continents

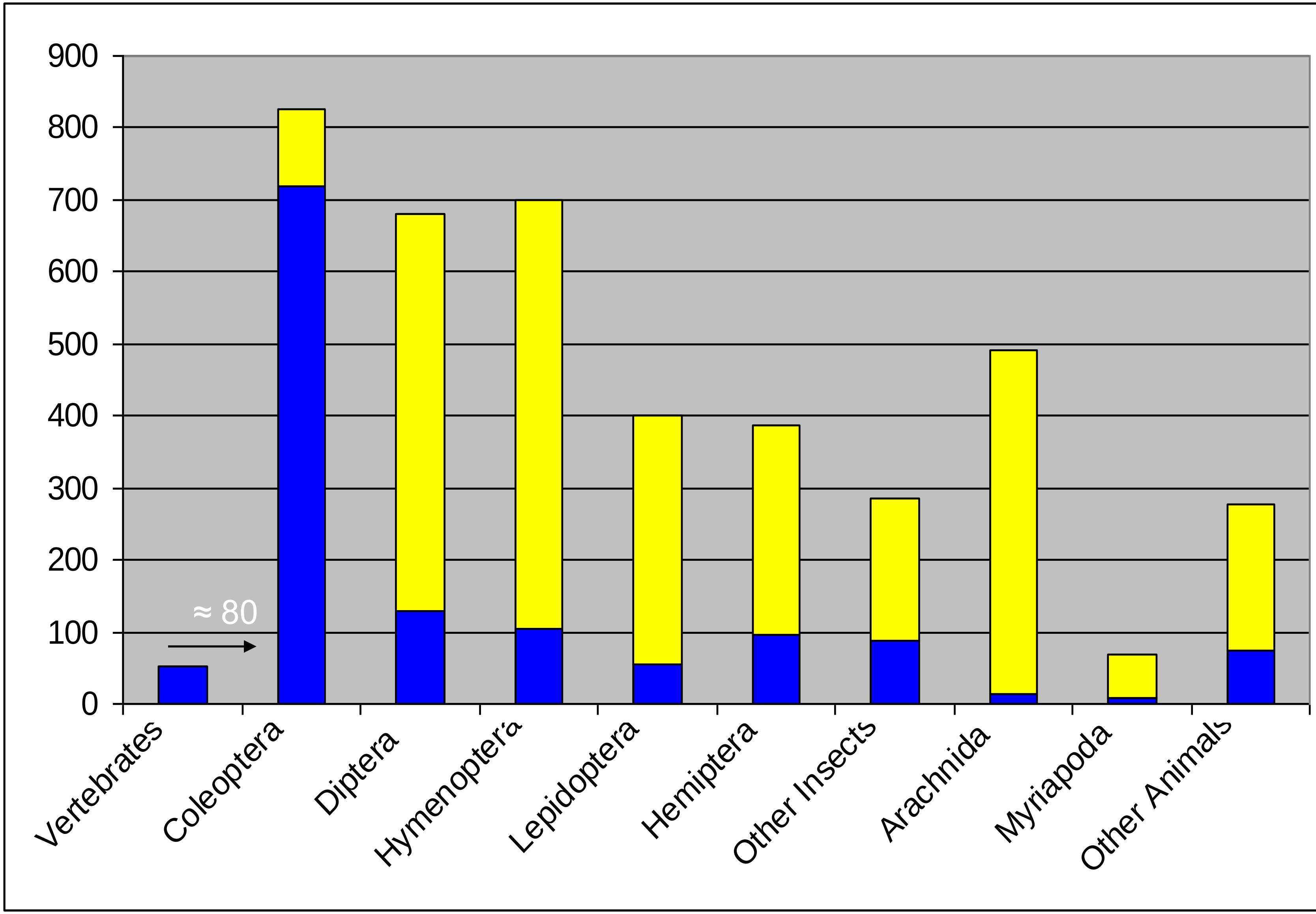
Some of the patterns in the results:



They are small in body size. Montserrat Beetle Species by Size Class. Includes 705 Species for Which Data Were Available (excludes 13 Scolytinae). Data were taken from a representative Montserrat specimen of each species, or, if not available, for a specimen from another island or the literature.



Most are "rare." Abundance of each species in the data set. These numbers were collected after obtaining and searching through approximately 1 million specimens of arthropods. The effort expended to reach this point has been huge. These data can be used to evaluate how close we have come in finding all the beetle species on Montserrat. Considering the total list of beetle species by number of observed specimens as a single collection and subjecting it to the Chao-1 estimator: S*1 = Sobs + (**a**2/2**b**), where "Sobs" is the number of species observed, "a" is the number of singletons, and "b" is the number of doubles (Chao 1984, Colwell 2005), gives an estimate of a mean expected 827 species, with a 95% CI of 792-876 (Calculated with EstimateS 7.5.1, Colwell 2005). This indicates that the current count of 718 species is probably about 87% of the expected total number of beetles, with a 95% chance that it is between 82 and 91% of the total.



Known vs. expected biodiversity of Montserrat animals. Blue represents recorded number of species, yellow represents predicted proportion of the fauna awaiting documentation.

What will we do in St. Lucia?

Field work: first trip, mostly SE part of island; 2nd trip, northern end?; 3rd trip, west central?; etc.

1. interacting with local people and officials; fields, forests, groves, stores and warehouses
2. visual and hand searching: of vegetation, under rocks, logs & bark, etc.
3. beating and sweeping of vegetation
4. Malaise (tent) traps combined with flight intercept traps, in fields and forests; <u>need secure locations</u>
5. fruit bait traps
6. pitfall traps baited with dung, carrion, etc.
7. blacklight traps at night
8. Berlese funnel extraction of beetles from soil and forest leaf litter
9. others


Insert pans or a trough to catch falling beetles


Ultraviolet "blacklight" light trap;
insects drown in soapy water
in bottom of bucket

Back to predictions based on Montserrat results

Chao estimator with 95% CI (calculated with EstimateS 7.5.1, Colwell 2005)

Island	*area*	*# now*	*estimated real number*
Montserrat**	**104 km^2**	**726+**	**827**
Grenada	**344 km^2**	**507**	**±1050**
St. Vincent	**389 km^2**	**408**	**±1100**
St. Lucia	**616 km^2**	**113**	**±1300 (10 x↑)**
Dominica	**751 km^2**	**361**	**±1400 (4x ↑)**

Conclusions: What can we expect to find?

1. A lot of specimens leading to <u>much</u> lab work in sorting and identification.

2. This will take time (5-10 years)

2. Expect body size and abundance patterns as in Montserrat

3. Many more species; From present 113+ species up to ± 1300 species

4. Other predictions? On origins, endemism, evolution, ecology, etc.

5. Things we cannot now expect or predict?

6. All of it will be an advancement in of understanding the natural heritage of St. Lucia and its place in the biological world.

Some predictions for beetles of the Lesser Antilles

Compared to continental Neotropical faunas : **after Ball 1992; for Carabidae; *Selenophorus* and *Apenes***

Colonizing fauna smaller in body size, and winged

From lowland sources

Main source is NE South America

No dramatic differences in lowland fauna

Endemics are in the highlands

Highland fauna is lower in species number

Wing reduction common in highland species

Rainforest species mostly derived from waterside ancestors (carabids)

Highland species derived from local waterside and lowland forest

Immigration rates to new islands vary: higher for waterside species; lowest for montane species

Movement from larger and more speciose land masses to smaller and less speciose land masses: i. e., from mainland and large islands to smaller islands