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.

Fig. 1. **Relative Biodiversity of Described Organisms** (Data from Chapman 2006).

So, *why* 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. **FLIGHT.** 95% of all insect species are winged – for escape, for efficiency in resource finding and exploitation, mate finding, etc.

7. **Metamorphosis.** 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. Larvae can act as ecologically different species.

8. **Fecundity.** 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 – **sociality** – 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 **bad**: 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 **very few in total**: 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 rest: some 750,000 species?

• III. **Neutral** 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 these 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 beetle

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

Neuroptera (ancestral) properties ➔ Beetle properties

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

Hind wings longer than body ➔ only hind wings used to fly
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 cucumber beetle
Curculionidae:
Long-horned weevils
Imported for weed control
Curculionidae
Alfalfa weevil
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>
<thead>
<tr>
<th>Hotspot</th>
<th>Endemic plants (% of global total, 300,000)</th>
<th>Endemic vertebrates (% of global total, 27,298)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical Andes*</td>
<td>20,000 (6.7)</td>
<td>1,567 (5.7)</td>
</tr>
<tr>
<td>Sundaland*</td>
<td>15,000 (5.0)</td>
<td>701 (2.6)</td>
</tr>
<tr>
<td>Madagascar*</td>
<td>9,704 (3.2)</td>
<td>771 (2.8)</td>
</tr>
<tr>
<td>Brazil’s Atlantic Forest*</td>
<td>8,000 (2.7)</td>
<td>567 (2.1)</td>
</tr>
<tr>
<td>Caribbean*</td>
<td>7,000 (2.3)</td>
<td>779 (2.9)</td>
</tr>
<tr>
<td><strong>Sub-totals (% rounded)</strong></td>
<td><strong>59,704 (19.9)</strong></td>
<td><strong>4,385 (16.1)</strong></td>
</tr>
<tr>
<td>Mesoamerica</td>
<td>5,000 (1.7)</td>
<td>1,159 (4.2)</td>
</tr>
<tr>
<td>Mediterranean Basin</td>
<td>13,000 (4.3)</td>
<td>235 (0.9)</td>
</tr>
<tr>
<td>Indo-Burma</td>
<td>7,000 (2.3)</td>
<td>528 (1.9)</td>
</tr>
<tr>
<td>Philippines</td>
<td>5,832 (1.9)</td>
<td>519 (1.9)</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>90,536 (30.1)</strong></td>
<td><strong>6,826 (25.0)</strong></td>
</tr>
</tbody>
</table>

* 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.
Table 4 Species/area ratios per 100 km² of hotspots

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<tr>
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<th>Endemic vertebrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical Andes</td>
<td>6.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Mesoamerica</td>
<td>2.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Caribbean</td>
<td>23.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Brazil’s Atlantic Forest</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Choco/Darien/Western Ecuador</td>
<td>3.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Brazil’s Cerrado</td>
<td>1.2</td>
<td>0.03</td>
</tr>
<tr>
<td>Central Chile</td>
<td>1.8</td>
<td>0.06</td>
</tr>
<tr>
<td>California Floristic Province</td>
<td>2.7</td>
<td>0.09</td>
</tr>
<tr>
<td>Madagascar</td>
<td>16.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Eastern Arc and Coastal Forests of Tanzania/Kenya</td>
<td>75</td>
<td>6.1</td>
</tr>
<tr>
<td>Western African Forests</td>
<td>1.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Cape Floristic Province</td>
<td>31.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Succulent Karoo</td>
<td>6.5</td>
<td>0.15</td>
</tr>
<tr>
<td>Mediterranean Basin</td>
<td>11.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Caucasus</td>
<td>3.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Sundaland</td>
<td>12.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Wallacea</td>
<td>2.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Philippines</td>
<td>64.7</td>
<td>5.7</td>
</tr>
<tr>
<td>Indo-Burma</td>
<td>7.0</td>
<td>0.5</td>
</tr>
<tr>
<td>South-Central China</td>
<td>5.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Western Ghats/Sri Lanka</td>
<td>17.5</td>
<td>2.9</td>
</tr>
<tr>
<td>SW Australia</td>
<td>13.0</td>
<td>0.3</td>
</tr>
<tr>
<td>New Caledonia</td>
<td>49.1</td>
<td>1.6</td>
</tr>
<tr>
<td>New Zealand</td>
<td>3.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Polynesia/Micronesia</td>
<td>33.3</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Caribbean Islands
Diversity and endemism
(Conservation International: [www.biodiversityhotspots.org](http://www.biodiversityhotspots.org))

<table>
<thead>
<tr>
<th>Taxonomic Group</th>
<th>Species</th>
<th>Endemic Species</th>
<th>Percent Endemism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants</td>
<td>13,000</td>
<td>6,550</td>
<td>50</td>
</tr>
<tr>
<td>Mammals</td>
<td>89</td>
<td>41</td>
<td>46</td>
</tr>
<tr>
<td>Birds</td>
<td>607</td>
<td>167</td>
<td>28</td>
</tr>
<tr>
<td>Reptiles</td>
<td>499</td>
<td>468</td>
<td>94</td>
</tr>
<tr>
<td>Amphibians</td>
<td>164</td>
<td>165</td>
<td>100</td>
</tr>
<tr>
<td>Freshwater Fishes</td>
<td>161</td>
<td>65</td>
<td>40</td>
</tr>
</tbody>
</table>

Conclusions:

Caribbean islands have many species per unit of land area.

They are well known for plant species; vertebrate species; butterflies; dragonflies. The rest is poorly known.
Now, what about St. Lucia? How many beetles are here?

We do not know!

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

The beetles of the Lesser Antilles: diversiy, distribution, and biogeography.

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 Engineering 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 what it means.

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?

<table>
<thead>
<tr>
<th>Land masses</th>
<th>area</th>
<th>known beetle species (ex. literature)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Greater Antilles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuba</td>
<td>111,000 km²</td>
<td>2673, Peck 2005</td>
</tr>
<tr>
<td>Hispaniola</td>
<td>76,000 km²</td>
<td>1700, Perez 2007</td>
</tr>
<tr>
<td>Puerto Rico &amp; Virgins</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Jamaica, Caymans, etc</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

Lesser Antilles: many northern smaller, drier, low islands

The following southern “high” wetter islands should be most diverse

<table>
<thead>
<tr>
<th>Montserrat**</th>
<th>104 km²</th>
<th>726+, Ivie 2007, 827+ projected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guadeloupe group</td>
<td>1693 km²</td>
<td>710+, Leng &amp; Mutchler 1917</td>
</tr>
<tr>
<td>Dominica</td>
<td>751 km²</td>
<td>361, Peck 2006a</td>
</tr>
<tr>
<td>Martinique</td>
<td>1100 km²</td>
<td>134+</td>
</tr>
<tr>
<td>St. Lucia</td>
<td>616 km²</td>
<td>113+</td>
</tr>
<tr>
<td>St. Vincent &amp; Grenadines</td>
<td>389 km²</td>
<td>408+</td>
</tr>
<tr>
<td>Barbados</td>
<td>430 km²</td>
<td>239, Bennett &amp; Alam 1985</td>
</tr>
<tr>
<td>Grenada</td>
<td>344 km²</td>
<td>507, Woodruff et al. 1998 (now 644)</td>
</tr>
</tbody>
</table>

Continental shelf islands and mainland

| Tobago                       | ?            | 672, Peck et al 2002                   |
| Trinidad                     | 5,130 km²    |                                        |
| South America                | ?            |                                        |
| Galapagos Islands            | 7882 km²     | 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 **much yet to discover**
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: $S^*1 = S_{obs} + \frac{a^2}{2b}$, where “$S_{obs}$” 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; 2\textsuperscript{nd} trip, northern end?; 3\textsuperscript{rd} 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; \textit{need secure locations}
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
A malaise trap set the insect flyway. 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)

<table>
<thead>
<tr>
<th>Island</th>
<th>area</th>
<th># now</th>
<th>estimated real number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montserrat**</td>
<td>104 km²</td>
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<td>344 km²</td>
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<td>±1050</td>
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<td>St. Vincent</td>
<td>389 km²</td>
<td>408</td>
<td>±1100</td>
</tr>
<tr>
<td>St. Lucia</td>
<td>616 km²</td>
<td>113</td>
<td>±1300 (10 x ↑)</td>
</tr>
<tr>
<td>Dominica</td>
<td>751 km²</td>
<td>361</td>
<td>±1400 (4x ↑)</td>
</tr>
</tbody>
</table>
Conclusions: What can we expect to find?

1. A lot of specimens leading to **much** 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