Hawaiian archipelago - the example for island biogeography

"Getting there is half the problem . . . but then they can't go home again"

Sherwin Carlquist, 1965

Hawaiian archipelago - the example for island biogeography

"Assume nothing in Hawaiian natural history"

Frank Howarth, 1992

4,169 m OR 13,679 ft
Hawaiian archipelago - *the example* for island biogeography

Most remote island system in the world

- settled in 1st millennium by Polynesians
- made known to science by Captain Cook in 1778

Hawaiian Biota

Hawaiian biota: most are found nowhere else in the world and exhibit traits uncharacteristic of their taxa

- around 1,000 species of flowering plants
- 225 species of ferns and allies

- nearly 5,800 species of insects
- 130 species of spiders

Happyface spider  Kamehameha butterfly

Hawaiian Biota

Hawaiian biota: most are found nowhere else in the world and exhibit traits uncharacteristic of their taxa

- 230 species of birds
- 800 species of terrestrial molluscs

Kauai O’o  Land snails
Hawaiian Biota

Hawaiian biota: most are found nowhere else in the world and exhibit traits uncharacteristic of their taxa

- no amphibians
- no terrestrial mammals

Hawaiian hoary bat
Hawaiian monk seal

Hawaiian Biota

Hawaiian hoary bat: extinction on-going process both in past and present

- arrived 320,000 years ago
- extinct 1,100 years ago

Extinct small Hawaiian bat

Hawaiian hoary bat: arrived 10,000 years ago

Hawaiian Archipelago

- 99% of land lies on 8 main islands near the hot spot below Lo‘ihi
- 132 islands, reefs, & shoals
- 2,580 km on SE-NW line

Hawaiian honeycreepers
Extinct snail, flightless duck, lobelias

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Hawaiian Archipelago

- Hot spot stationary relative to Pacific Plate motion
- Forms hot spot trace
- Potassium-argon dating indicates oldest islands furthest from hot spot
- Newest island Loihi still underwater - seamount

- Plate motion changed 43 mya
- Oldest seamounts subducted into Aleutian Trench

Hawaiian Archipelago

- Islands (and shoals) are simply emergent tops of great underwater volcanoes
- Up to 10km above ocean floor
  - Mauna Kea – 10.2 km (4.2 km)
  - Maua Loa - 37 m lower but most massive

- Actually double hot spot 30km apart
- Lo’ihi to Mauna Loa
- Kilauea to Mauna Kea

USGS ‘GLORIA’ side sonar

Mauna Loa
Hawaiian Climate

- primary weather pattern is northeasterly trade winds
- severe kona winds come from leeward side

Hilo (windward and wet) vs. Kona Coast in Hawaii (leeward and dry)

Hawaiian Climate

- double mountain system (as in Oahu) sets up complex rainfall gradient and a diversity of ecosystems

Wai'ale'ale on oldest (most eroded) island of Kauai is wettest spot in Hawaii and possibly in the world

- 11.5 m of rain and presence of the Alakai Swamp

- extraordinary rich and diverse habitats available
- 38 community types recognized

Rainfall patterns

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Wai'ale'ale on oldest (most eroded) island of Kauai is wettest spot in Hawaii and possibly in the world

- 11.5 m of rain and presence of the Alakai Swamp
Hawaiian Climate

- rainfall patterns
  - Pu’ukukui (5,788 ft) on west Maui is 2nd wettest spot; xeric summit of Haleakala on east Maui is 10,023 ft

Greensword bog - west Maui

Flora of Hawaii

- since so isolated, it has a depauperate flora and consists entirely of waif elements derived from LDD
  - native
  - or weeds

Argyrotrichium sandwicense - Haleakala silversword
Passiflora mollissima - Banana poka

Flora of Hawaii

- individual islands tend to fit the expected number of species based on area - except most recent Hawaii

Figure 5  Species–area regression for whole islands. Abbreviations are given in Table 2.
Flora of Hawaii

- Endemism high in flowering plants (highest in world)

956 native species 1,817 including introduced
  • 89% endemic
216 native genera 649 including introduced
  • 15% endemic
87 native families 146 including introduced
  • 0% endemic

Flora of Hawaii

- Disharmonic flora

- Only 3 native orchid species
- But many introduced orchids that become naturalized

Dendrobium & honey bees

Flora of Hawaii

- Disharmonic flora

- Only 1 native palm genus (coconut?)
- Native gymnosperms and primitive angiosperms absent

Pritchardia beccariana

Flora of Hawaii

- Disharmonic flora - 15 largest families of native species

<table>
<thead>
<tr>
<th>Family</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campanulaceae</td>
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<tr>
<td>Asteraceae</td>
<td>92</td>
</tr>
<tr>
<td>Rutaceae</td>
<td>55</td>
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<td>Lamiaceae</td>
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<td>Rubiaceae</td>
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<td>Gesneriaceae</td>
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<td>Piperaceae</td>
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<td>Euphorbiaceae</td>
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<td>Fabaceae</td>
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<tr>
<td>Solanaceae</td>
<td>5</td>
</tr>
<tr>
<td>Myrtaceae</td>
<td>4</td>
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</table>
**Flora of Hawaii**

- **Immigrants**: 270 (or less!) gave rise to 956 native angiosperms

  - 1/10th of colonist generates 1/2 of species!

  - Similar story with other biota:
    - One American finch gave rise to 33 extant and 14 extinct species of honeycreepers.

  - 800 land molluscs from 20 colonists

  - 5,800 insects from 250 colonists

  - But different story for ferns!
    - 168 ferns from 135 colonists - implying constant immigration (lack of genetic isolation) and/or few speciation events.

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**TABLE 1: Twenty most speciose genera of Hawaiian flowering plants and percent number of colonists.**

<table>
<thead>
<tr>
<th>Genus</th>
<th>Number of species</th>
<th>Percent number of colonists</th>
</tr>
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<tbody>
<tr>
<td>Cyrtandra</td>
<td>55</td>
<td>6-6</td>
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<tr>
<td>Cyanea</td>
<td>3</td>
<td>1-1</td>
</tr>
<tr>
<td>Pelea</td>
<td>4</td>
<td>1-1</td>
</tr>
<tr>
<td>Cyanea</td>
<td>1</td>
<td>1-1</td>
</tr>
<tr>
<td>Pelea</td>
<td>1</td>
<td>1-1</td>
</tr>
<tr>
<td>Cyanea</td>
<td>1</td>
<td>1-1</td>
</tr>
<tr>
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<td>Pelea</td>
<td>1</td>
<td>1-1</td>
</tr>
</tbody>
</table>

**Sadleria** - 6 species

**Polypodium** - 1 species
Flora of Hawaii

- LDD mechanisms

1% A air
39% BI internal
13% BM mud
10% BV viscid
12% BB barbs/hooks
14% DF drift
9% DR drift - rare

Flora of Hawaii

- floristic affinities

Leptocophylla BI

Argyroxiphium BB

Acacia - koa DR

Viola BM

Flora of Hawaii

- floristic affinities

Leptocophylla
Epacridaceae

- despite proximity of Hawaii to N America, almost half of colonists are of Austral-asian origin

Flora of Hawaii

- floristic affinities

Viola

- few from Arctic-Beringia

Plantago - plantain

Flora of Hawaii

- floristic affinities

Viola langsdorffii

- woody violets once considered closely related to South American violets
- all native Hawaiian violets are polyploid and derived from polyploid races of one Beringian tundra species - the Alaskan violet
Flora of Hawaii

• floristic affinities

Argyroxiphium

• 18-22% from western North America

Flora of Hawaii

• adaptive radiation of Hawaiian silverswords

• silversword alliance of 3 genera and 28 species

• trees, shrubs, subshrubs, rosette plants, cushion plants, vines

B. Baldwin verified that the Hawaiian silversword radiation derived from California

• the closest species is now called Carlquistia muirii
• this origin occurred about 5 mya
• rapid radiation at base

inter-island biogeography ["island hopping” – “stepping stones”]

• most speciation events occur on individual islands
• few successful inter-island colonizations
• movement is from older to younger islands

Rosemary Gillepsie
Flora of Hawaii

• extinction: on-going process on islands (as well as immigration)

• but due to humans . . .
  • 107 of 956 angiosperm species — 11% extinct
  • 423 of 956 species — 38% extinct or threatened

Flora of Hawaii

• extinction: rogue gallery of exotics

Passiflora mollissima - banana pokā

Miconia calvescens
“green cancer”
Hawaiian Lobeliads

Why the Hawaiian lobeliads?

- largest group: 6 genera, 140 species
- 1/8th of native flora
- considered derived from 3-5 separate colonizations
- phenomenal variation in habitat, life form, flowers, and fruits

Hawaiian Lobeliads

DNA supports common ancestry of ALL Hawaiian lobeliads – one single ancestral seed dispersed to Hawaii & radiated into the more than 140 species
Two approaches for dating and placing the Hawaiian colonization

1. Calibration using an external phylogeny of the order Asterales and 5 well characterized fossils outside the family

Two clock calibrations - using Asterid fossils or using Hawaiian Island ages - place the differentiation of Hawaiian lobelioids at 13-14 mya

Original colonist arrived in LaPerouse/Gardner Pinnacles - large volcanic islands 10-15 mya
Hawaiian Lobeliads

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Original colonist arrived in LaPerouse/Gardner Pinnacles - large volcanic islands 10-15 mya.

Hawaiian Lobeliads

One of the oldest radiations of extant Hawaiian biota - honeycreeper pollinators would not arrive for another 7-9 my.

But . . . a 2008 paper shows that the 5 recently extinct Hawaiian Honeyeaters – thought to be recently derived from AustralAsian Honeyeaters – are in fact 14-17 my old and derived from an American clade - waxwings, silky flycatchers, and palm chats.

Hawaiian Honeycreepers 7 mya

• Early lobeliads had initial radiation with Hawaiian honeyeaters

• later radiation of two large genera (Cyanea and Clermontia) primarily with Hawaiian honeycreepers
“Assume nothing in Hawaiian natural history”