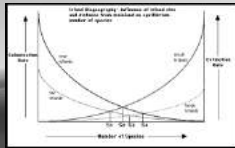


## Biogeography of Hawaii



Island biogeography



Adaptive radiations

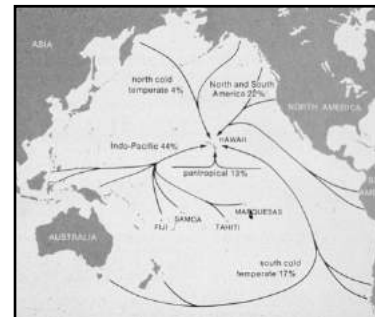


Dispersal

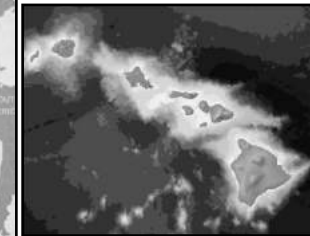
We will integrate all three island phenomena  
in the context of the Hawaiian Islands

## Hawaiian archipelago - *the example* for island biogeography

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



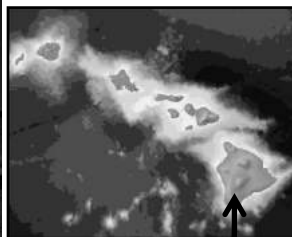
Sherwin Carlquist, 1965



## Hawaiian archipelago - *the example* for island biogeography

*"If one were to stand at the top of Mauna Loa, he could see  
all the climes of the world at a single glance of the eye"*

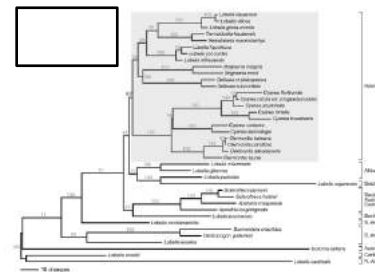
Mark Twain, 1866



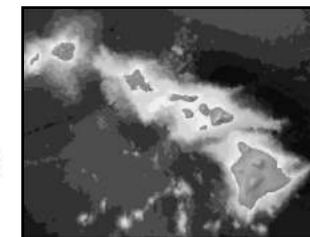
4,169 m OR 13,679 ft

## Hawaiian archipelago - *the example* for island biogeography

*"Assume nothing in Hawaiian natural history"*

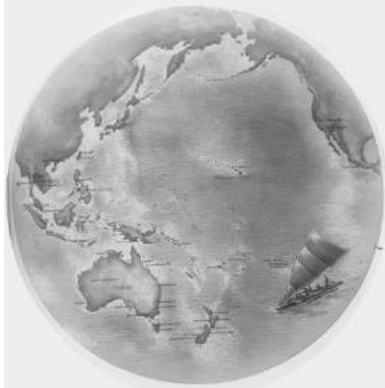


Frank Howarth, 1992



## Hawaiian archipelago - *the example* for island biogeography

Most remote island system in the world



- settled in 1st millenium 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

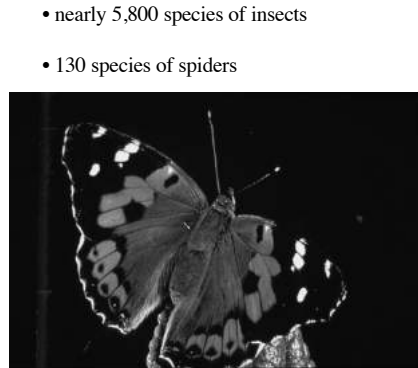


## Hawaiian Biota

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



Happyface spider



Kamehameha butterfly

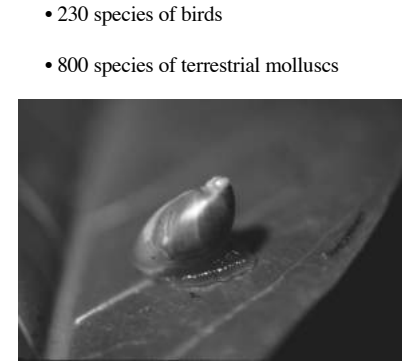
- nearly 5,800 species of insects
- 130 species of spiders

## Hawaiian Biota

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



Kauai O' o



Land snails

- 230 species of birds
- 800 species of terrestrial molluscs

## 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 biota: extinction on-going process both in past and present



Hawaiian hoary bat  
• arrived 10,000 years ago



Extinct small Hawaiian bat  
• arrived 320,000 years ago  
• extinct 1,100 years ago

## Hawaiian Biota

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



Extinct snail, flightless duck, lobeliad



from left to right  
Kauai O'O Extinct, Kauai Akialaka Extinct, O'u Extinct,  
Kauai Nukupu's Extinct, Puaichi less than 200 remain, Kamao Extinct

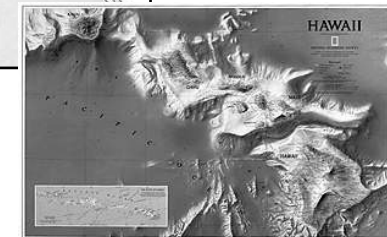
Hawaiian honeycreepers

## Hawaiian Archipelago

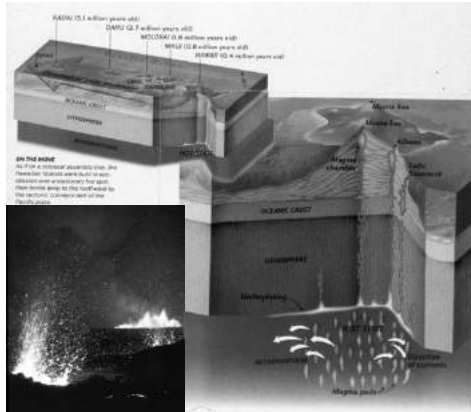


• 99% of land lies on 8 main islands near the hot spot below Lo' ihi

- 132 islands, reefs, & shoals
- 2,580 km on SE-NW line

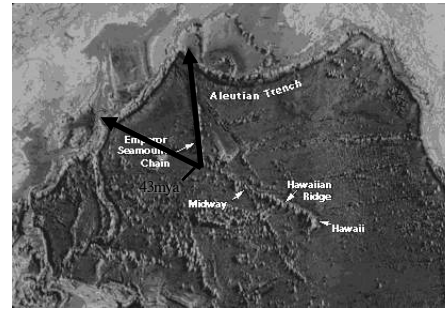


## Hawaiian Archipelago



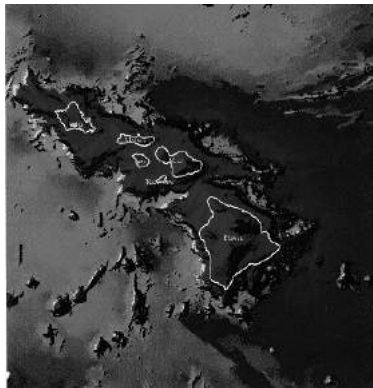
- hot spot stationary relative to Pacific Plate motion
- forms hot spot trace
- potassium-argon dating indicates oldest islands furthest from hot spot
- newest island Loihi still underwater - seamount

## Hawaiian Archipelago



- plate motion changed 43 mya
- oldest seamounts subducted into Aleutian Trench

## Hawaiian Archipelago



USGS 'GLORIA' side sonar

- 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)

Mauna Loa - 37 m lower but most massive



Mauna Loa

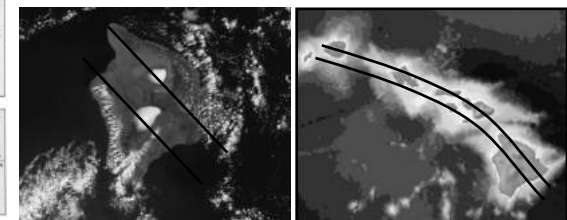
## Hawaiian Archipelago



- actually double hot spot 30km apart
- Lo' ihi to Mauna Loa
- Kilauea to Mauna Kea

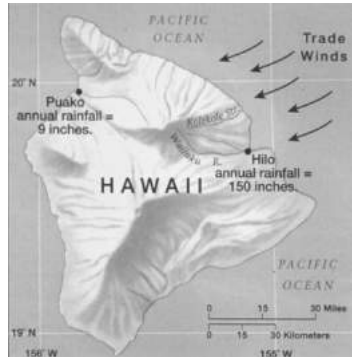
Oahu

Hawaii



## 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

rainfall patterns

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



Figure 10. The Ko'olau Mountains, which run perpendicular to the direction of the trade winds, condense most of the moisture from this moist air. The Waianae Mountains are in a rain shadow. Only Mt. Ka'ala in the Waianae Mountains is high enough to receive much moisture from the trade winds.



## Hawaiian Climate

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



## Hawaiian Climate

rainfall patterns

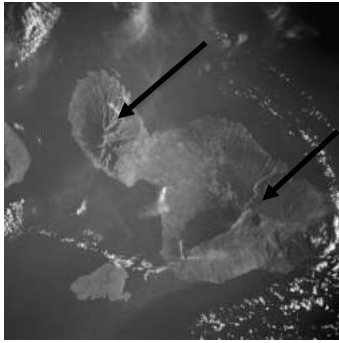
- Wai'ale'ale on oldest (most eroded) island of Kauai is wettest spot in Hawaii and possibly in the world



- 11.5 m of rain and presence of the Alakai Swamp



## Hawaiian Climate



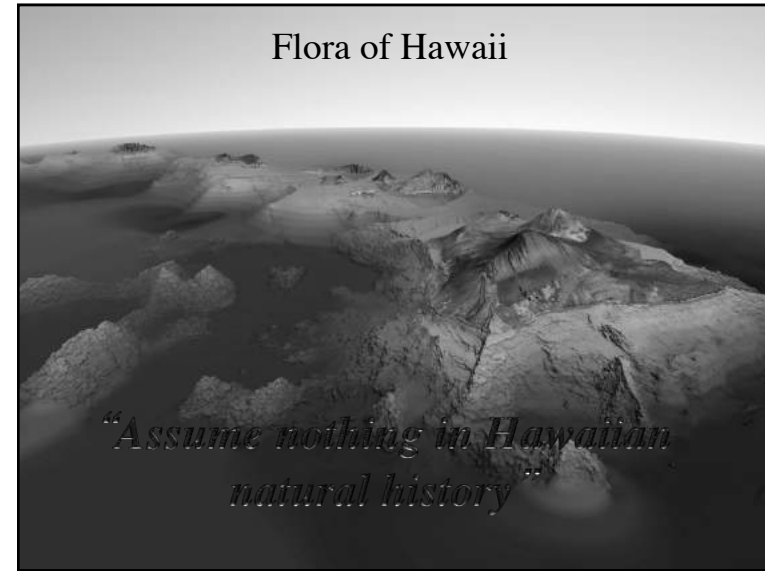
rainfall patterns

- 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



## Flora of Hawaii

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

native



*Argyroxiphium sandwicense* - Haleakala silversword



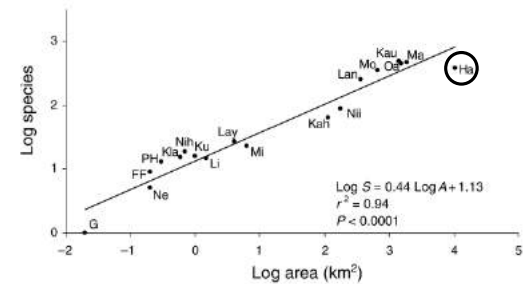
or weeds



*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

- 89% endemic

216 native genera

- 15% endemic

87 native families

- 0% endemic

1,817 including introduced

649 including introduced

146 including introduced



## 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

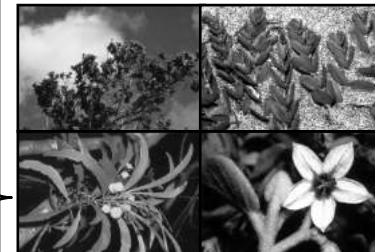
- disharmonic flora - 15 largest families of native species

Campanulaceae	110
Asteraceae	92
Rutaceae	55
Lamiaceae	54
Rubiaceae	54
Gesneriaceae	53
Poaceae	47
Cyperaceae	45
Caryophyllaceae	33
Piperaceae	25
Malvaceae	24
Euphorbiaceae	21
Fabaceae	20
Solanaceae	9
Myrtaceae	8



- large source area families under represented

- small Campanulaceae - lobeliads and bellflowers - over represented







## Flora of Hawaii

- LDD mechanisms

1%	A	air	74%
39%	BI	internal	
13%	BM	mud	
10%	BV	viscid	
12%	BB	barbs/hooks	
14%	DF	drift	
9%	DR	drift - rare	



*Argroxiphium* BB



*Leptocophylla* BI



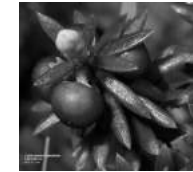
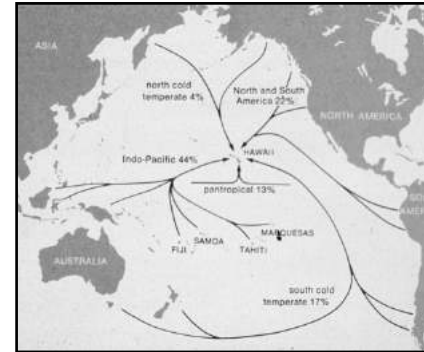
*Acacia - koa* DR



*Viola* BM

## Flora of Hawaii

- floristic affinities

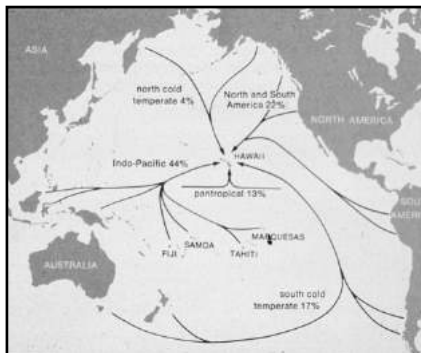


*Leptocophylla*  
Epacridaceae

- 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 langsdorfii*

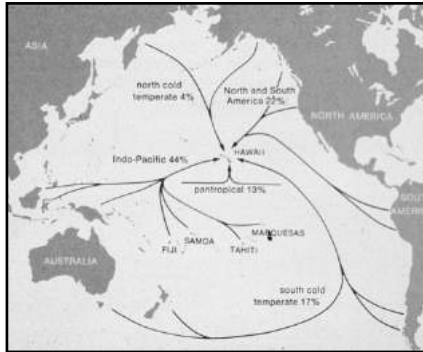


*Viola*

- 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



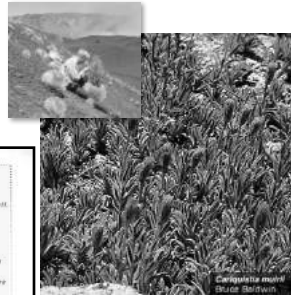
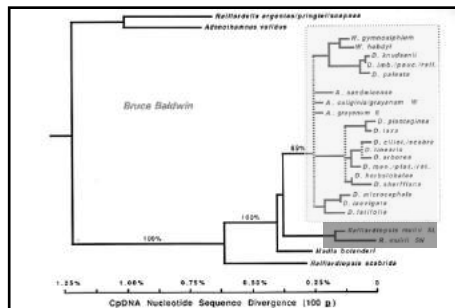
- silversword alliance of 3 genera and 28 species

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

## Flora of Hawaii

- adaptive radiation of Hawaiian silverswords

- 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

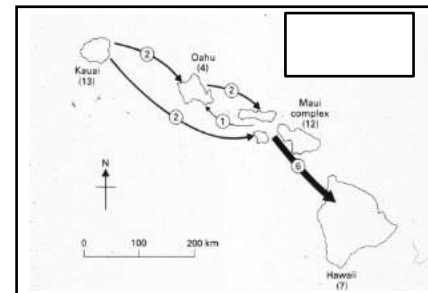
## Flora of Hawaii

- 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



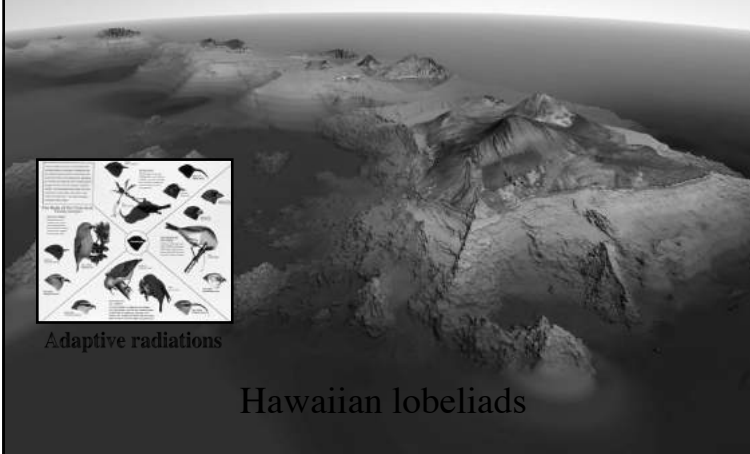
Rosemary Gillespie



*Argyroxiphium*



## Biogeography of Hawaii



## Hawaiian Lobeliads

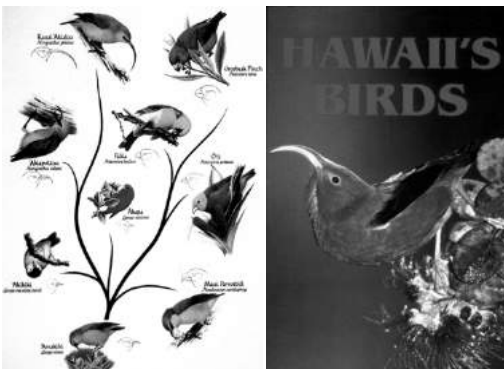
Why the Hawaiian lobeliads?



- 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

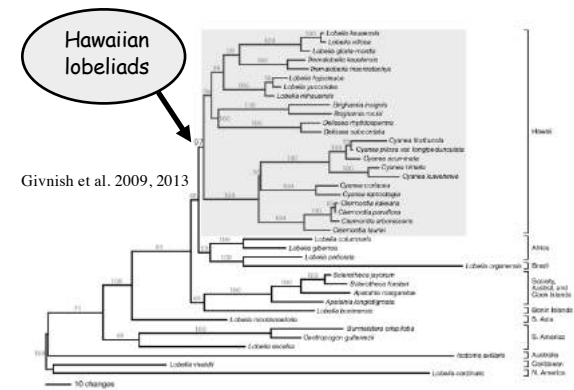
## Hawaiian Lobeliads

Why the Hawaiian lobeliads?



- appear to have co-evolved with the endemic Hawaiian honeycreepers
- honeycreepers represent a separate adaptive radiation

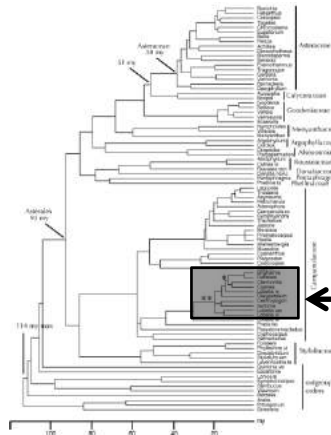
## Hawaiian Lobeliads



DNA supports common ancestry of ALL Hawaiian lobeliads – one single ancestral seed dispersed to Hawaii & radiated into the more than 140 species

## Hawaiian Lobeliads

Two approaches for dating and placing the Hawaiian colonization

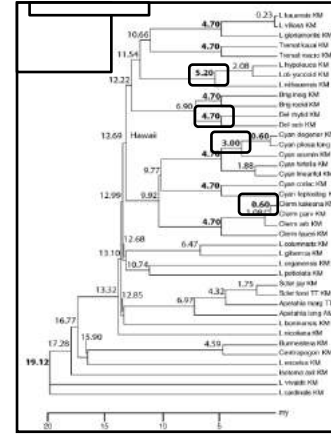


1. Calibration using an external phylogeny of the order Asterales and 5 well characterized fossils outside the family

Hawaiian lobelioids

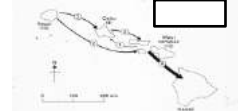
## Hawaiian Lobeliads

Two approaches for dating and placing the Hawaiian colonization



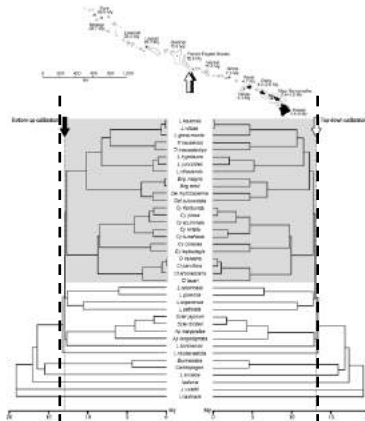
2. Calibration using island shifts / island ages

- Nihau vs. Kauai
- Kauau vs. Ohau
- Ohau vs. Maui
- Maui vs. Hawaii



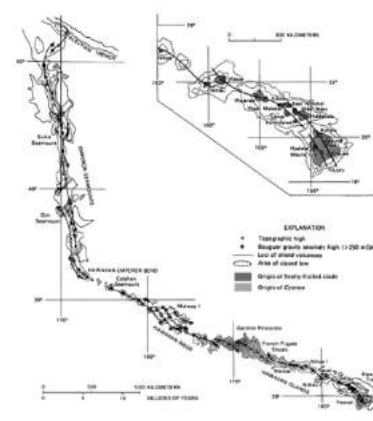
## Hawaiian Lobeliads

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



## Hawaiian Lobeliads

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



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

## Hawaiian Lobeliads

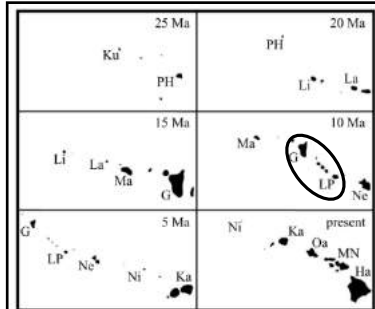
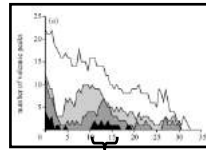


Figure 3. Island configurations at 5 Myr intervals. We adjusted a rough digital elevation model of the estimated pre-erosion surface according to height estimates for different points in time. Ku, Kure; PH, Pearl and Hermes; Li, Lisianski; La, Laysan; Ma, Maro; G, Gardner; LP, LaPerouse; Ne, Necker; Ni, Nihoa; Ka, Kauai; Oa, Oahu; MN, Maui Nui; Ha, Hawaii.

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

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

*Hawaii and the Hawaiian biota* J. P. Price and D. A. Chappie 2433

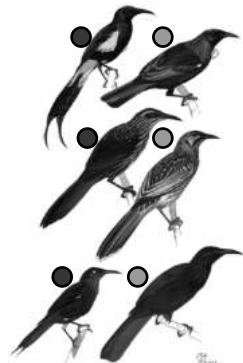
Table 1. Age estimates for MRCA's of lineages of Hawaiian organisms.\*

lineage	type of organism	no. of species	age (Ma)	method	source
Hawaiian fruitflies (Drosophilidae)	insect	ca. 1000	20	EC	Bawa et al. (1995)
Hawaiian lobeliads (Campanulidaceae)	plant	125	15	EC	Givnish et al. (1994)
<i>Melospiza dominicensis</i> (Troglodytidae)	insect	25	9.0	EC	Jordan et al. (2007)
Scolecophoran Alluaea (Amphisbaenidae)	plant	26	9.1	EC	Balshine & Sanderson (1998)
Laysan duck, <i>Anas wyvilliana</i> (Anatidae)	bird	1	< 5	EC	Fleischer & Malmosh (2001)
Hawaiian crossbills, <i>Certhia acuminata</i> + other spp. (Cerambycidae)	bird	1+?	< 4.2	EC	Fleischer & Malmosh (2001)
Hawaiian honeycreepers, <i>Reopanax</i> (Troglodytidae)	bird	ca. 30	4-6	EC	Fleischer et al. (1998)
Vireo spp. (Vireonidae)	bird	6	3.7	BS, LD	Balshine & Szymura (2000)
flightless Anseriformes, 'mou-walas' (Anseridae)	bird	4	< 3.0	EC	Satirson et al. (1999)
Hawaiian thrushes, <i>Molodens</i> spp. (Mniotiltidae)	bird	5	< 3.35	EC	Fleischer & Malmosh (2001)
Koala spp. (Mammalia)	plant	4	< 3	EC	Sedberry et al. (1997)
flightless rails, <i>Porzana sandwicensis</i> + other spp. (Rallidae)	bird	1+?	< 2.95	EC	Fleischer & Malmosh (2001)
Gallinule spp. (Gallinaceae)	plant	6	2	BS	Funk & Wagner (1997)
Hesperomys spp. (Rodentia)	plant	4	1.80-4.91	EC	Karr et al. (1996)
flightless terns, <i>Sterna</i> spp. (Sternidae)	bird	2	< 1.6	EC	Fleischer & Malmosh (2001)
Hawaiian duck, <i>Anas wyvilliana</i> (Anatidae)	bird	1	< 1.5	EC	Fleischer & Malmosh (2001)
flightless rails, <i>Porzana palauensis</i> + other spp. (Rallidae)	bird	1+?	< 1.05	EC	Fleischer & Malmosh (2001)
Hawaiian crossbills, <i>Branta</i> spp. (Anatidae)	bird	3	< 1	EC, LD	Fleischer & Malmosh (2001)
Hawaiian black-necked stilts, <i>Himantopus mexicanus</i> (Columbidae)	bird	1	< 0.75	EC	Fleischer & Malmosh (2001)
Hawaiian monk seal, <i>Monachus</i> (Carnivora)	bird	1	< 0.7	EC	Fleischer & Malmosh (2001)
Tanagers spp. (Amerezae)	plant	11	0.8-0.2	EC, LD	Lorenz (1999)
Molodens spp. (Mammalia)	plant	5	0.5-1.0	LD	Wright et al. (2001)



## Hawaiian Lobeliads

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



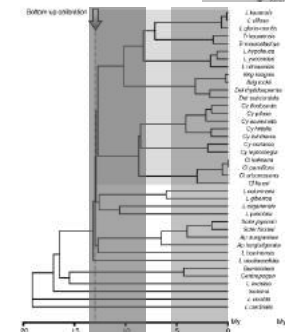
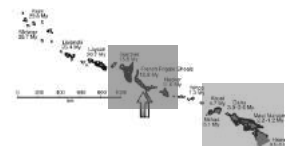
Hawaiian lobeliads 13-14 mya

Hawaiian Honeycreepers 7 mya



Figure 2. Illustrations of three of the five species of Hawaiian Honeycreepers and three Hawaiian Honeycreeper. The three Hawaiian taxa represent the three primary morphological types found in Hawaiian Honeycreepers (Molokai, Oahu, and Kauai). Other species include one from New Zealand (NZ), *Phylloscopus collybitz*, one from Australia (AU), *Artamus leucorhynchus*, and one from Samoa (SM), *Cyanocitta stelleri*. Illustrations are by John Anderson and are used here with permission.

## Hawaiian Lobeliads



• Early lobeliads had initial radiation with Hawaiian honeyeaters

• later radiation of two large genera (*Cyanea* and *Clermontia*) primarily with Hawaiian honeycreepers



