Biogeography of Islands

‘Insular Syndrome’

24 principles

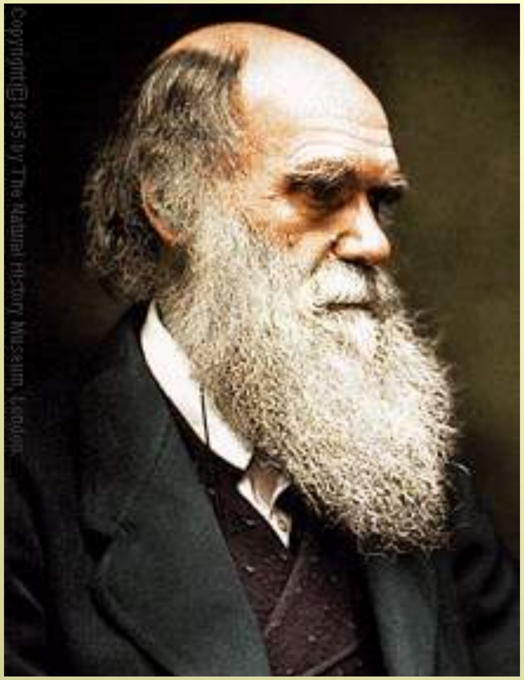
1. difficulties of LDD to islands
2. isolation after establishment
3. ecological opportunities
4. moderation of maritime climate

Adaptive radiations

Dispersal

Dispersal Biology

Charles Darwin (1809–1882)



• LDD key to Darwin's view of disjunct biogeographical distributions

"... they spread as far as barriers, the means of transportal, and the preoccupation of the land by other species, would permit"

"It certainly is the general rule that the area inhabited by a single species or by a group of species is continuous and the exceptions, which are not rare . . . be accounted for by former migrations under different circumstances, or through occasional means of transport, or by the species having become extinct in the intermediate tracts"

(Darwin, 1859)

Dispersal Biology

• Darwin's experiments on long distance dispersal (LDD) at Down House

Problem: all sunk to bottom of vials!

• 87 plant species examined

• 64 germinated after an immersion of 28 days in salt water tanks

• few germinated even after 137 days of immersion

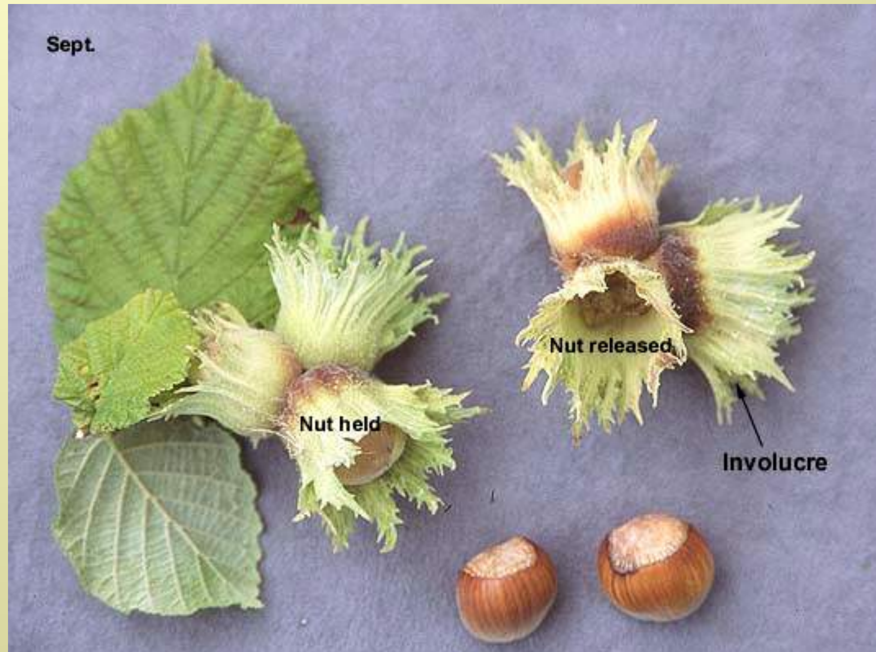
• the laboratory: cellar at Down House

Dispersal Biology

• Darwin extended these experiments by demonstrating dehydrated seeds and stems floated better

• asparagus floated for 32 days and then germinated

• Darwin concluded, based on Atlantic current speeds (33 miles/day), that seeds floating 28 days would travel 924 miles at sea



• hazelnut stems with fruits floated for 90 days and then germinated

Dispersal Biology

• Darwin also studied other, more irregular, means of transport

• attached to feet or feathers of birds, or inside the gizzard or digestive tract

Hawaiian *nene*

Dispersal Biology

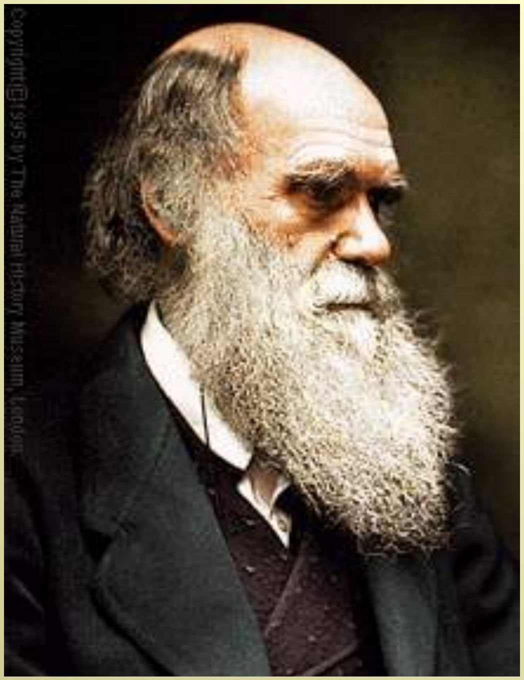
• Darwin also studied other, more irregular, means of transport

• suspended duck feet in aquarium stocked with freshwater snails

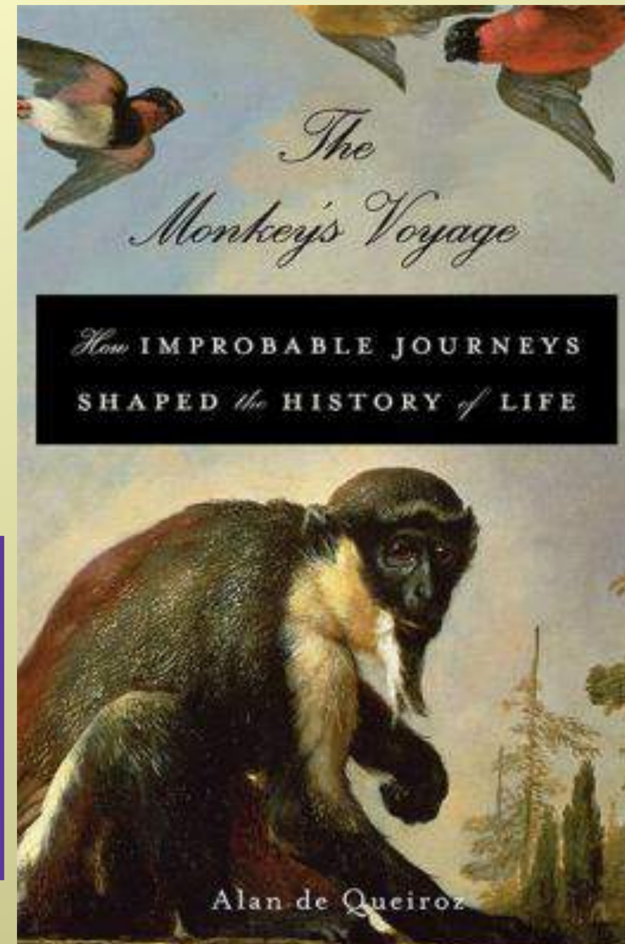
• molluscs crawled on, clung tightly in air for 12-20 hours — Darwin argued that duck or heron would have flown 700 miles

Dispersal Biology

- Fast forward to 2019 - Darwin was both right and wrong



- Trans-oceanic dispersal now clearly supported
- Continents, clades, and clock evidence



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The resurrection of oceanic dispersal in historical biogeography

Alan de Queiroz

Dispersal Biology

• deQueiroz (2005) *Trends in Ecology and Evolution*

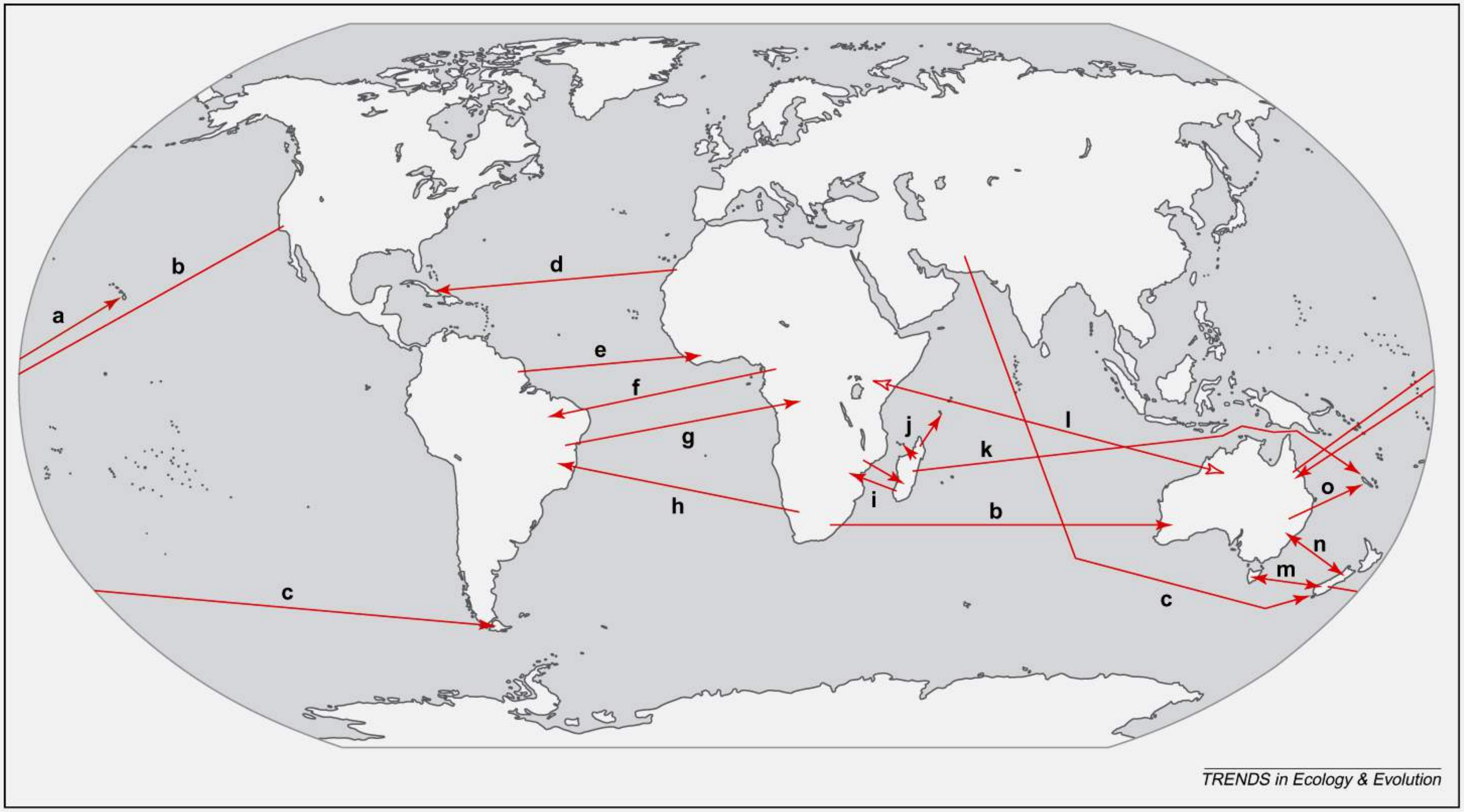


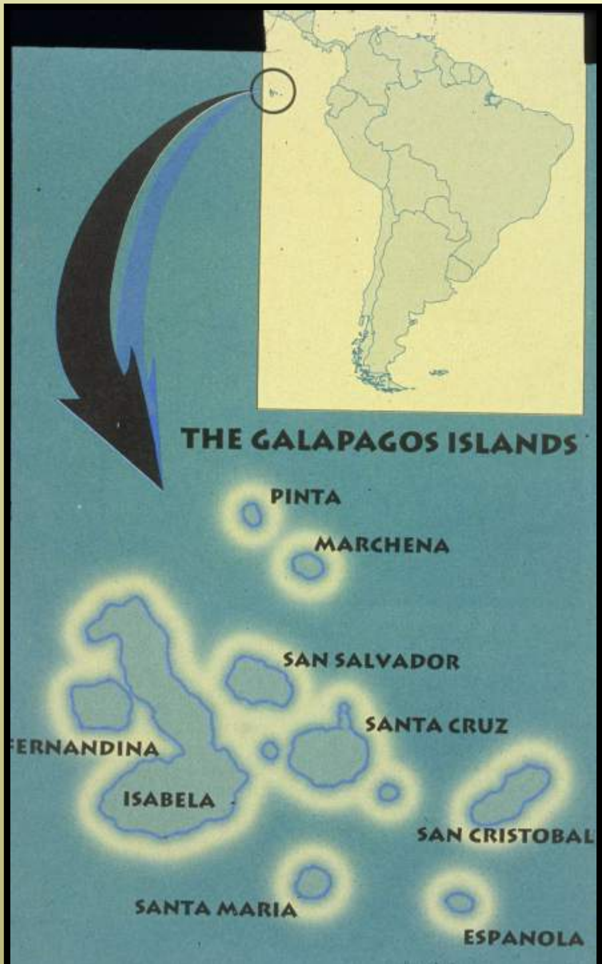
Figure 1. Striking examples of oceanic dispersal. **(a)** *Scaevola* (Angiospermae: Goodeniaceae) three times from Australia to Hawaii [48]; **(b)** *Lepidium* mustards (Angiospermae: Brassicaceae) from North America and Africa to Australia [49]; **(c)** *Myosotis* forget-me-nots (Angiospermae: Boraginaceae) from Eurasia to New Zealand and from New Zealand to South America [29]; **(d)** *Tarentola* geckos from Africa to Cuba [50]; **(e)** *Maschalocephalus* (Angiospermae: Rapateaceae) from South America to Africa [24]; **(f)** monkeys (Platyrrhini) from Africa to South America [18]; **(g)** melastomes (Angiospermae: Melastomataceae) from South America to Africa [40]; **(h)** cotton (Angiospermae: Malvaceae: *Gossypium*) from Africa to South America [51]; **(i)** chameleons three times from Madagascar to Africa [19]; **(j)** several frog genera to and from Madagascar [21]; **(k)** *Acridocarpus* (Angiospermae: Malpighiaceae) from Madagascar to New Caledonia [23]; **(l)** Baobab trees (Angiospermae: Bombacaceae: *Adansonia*) between Africa and Australia [13]; **(m)** 200 plant species between Tasmania and New Zealand [35]; **(n)** many plant taxa between Australia and New Zealand [8,28,29]; and **(o)** *Nemuaron* (Angiospermae: Atherospermataceae) from Australia (or Antarctica) to New Caledonia [25]. Unfilled arrows on both ends of a line indicate uncertain direction of dispersal. Filled arrows on both ends indicate dispersal in both directions.

Galapagos Flora

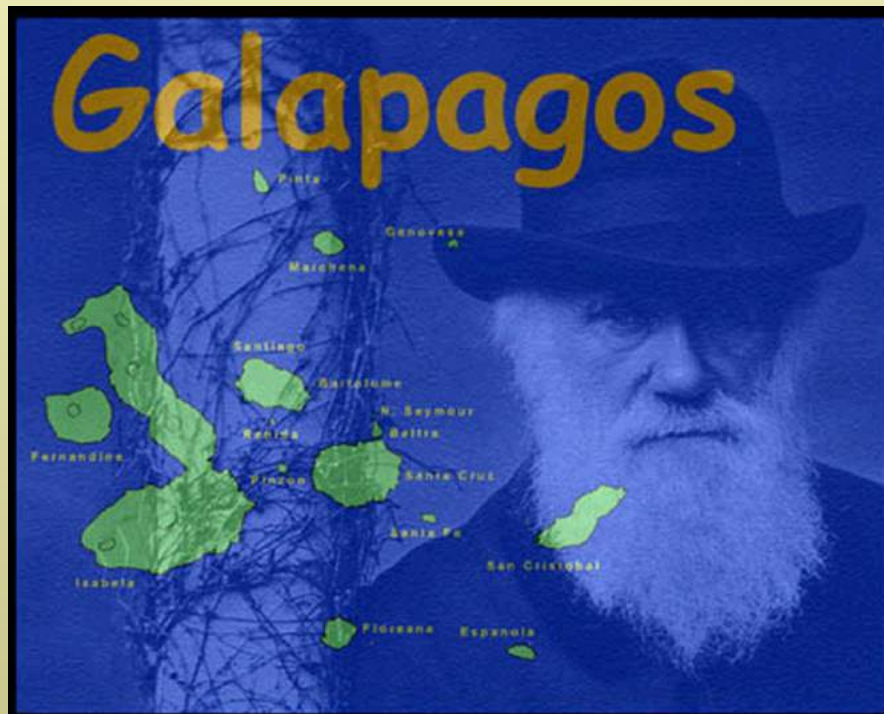
• volcanic islands, 800 km from continental source area

• 522 (550 in 2019) indigenous (native) vascular species

• 181 (880 in 2019) introduced 'weeds' - a feature of island biogeography

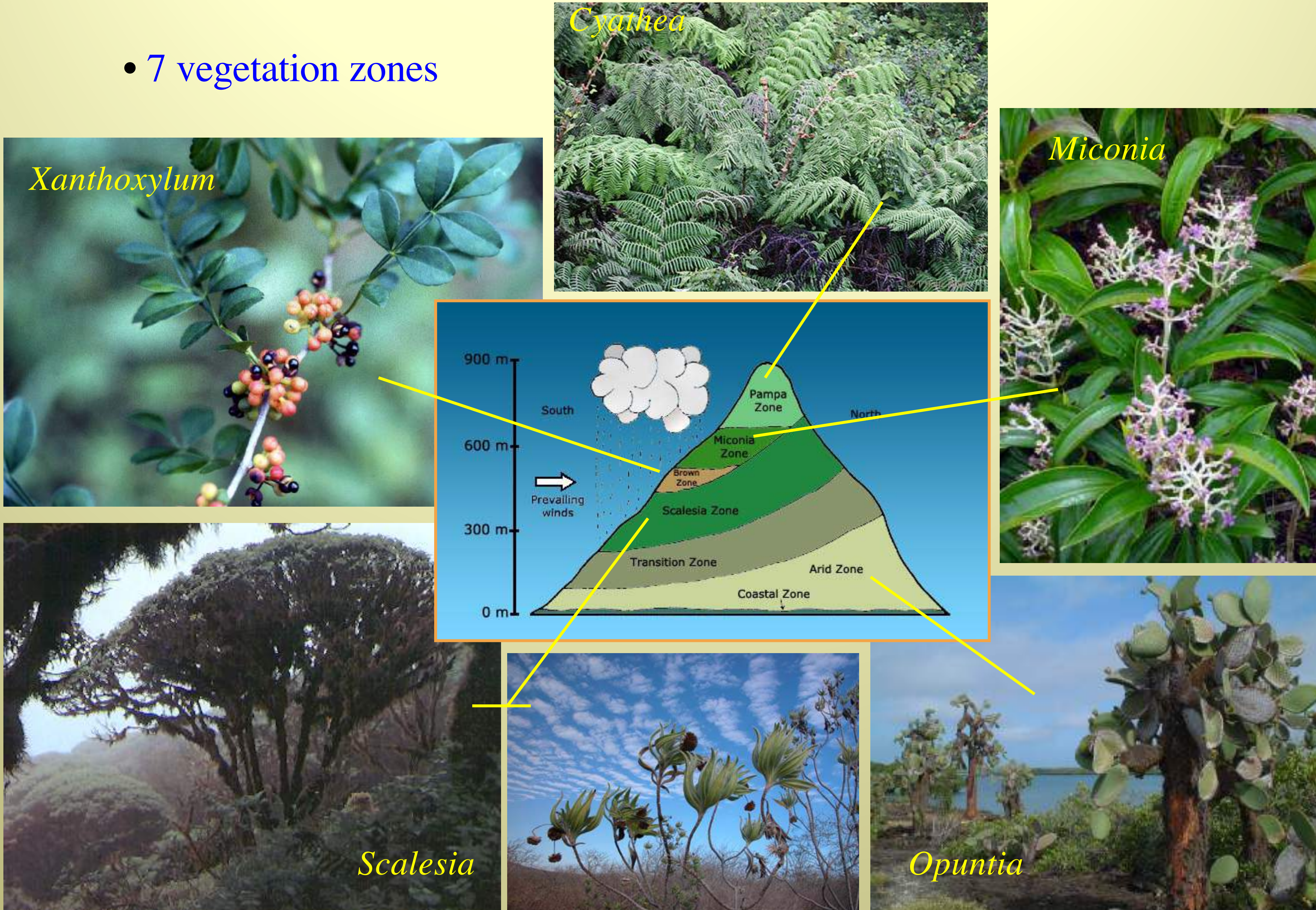


Duncan Porter 1976 "*Geography and dispersal of Galapagos Islands vascular plants*" Nature 264:745-746



Galapagos Flora

- 7 vegetation zones



Galapagos Flora

Indigenous flora - make up of an island biota

- 522 native species – depauperate!
- 45% of species are endemic to the islands
- ferns and relatives have low endemism
- 98+% of non-endemic species also occur in South America – source!

Table 1 Geographical relationships of the indigenous vascular plants of the Galapagos Islands

	Endemic	Neotropical	Pantropical	Andean	Mexico and Central America	South America	Total
Pteriodophytes	8	52	14	15		2	91
Monocotyledons	20	38	22	3			83
Dicotyledons	208	65	26	43	4	2	348
Total	236 (45%)	155 (30%)	62 (12%)	61 (12%)	4 (1%)	4 (1%)	522

Galapagos Flora

How did the plants get there?

• 181 non-native species by 1976 in addition to 522 native species
• humans are a big disperser!

• Hooker (1847) commented on aliens
• 475 by 1999
• 600+ species today

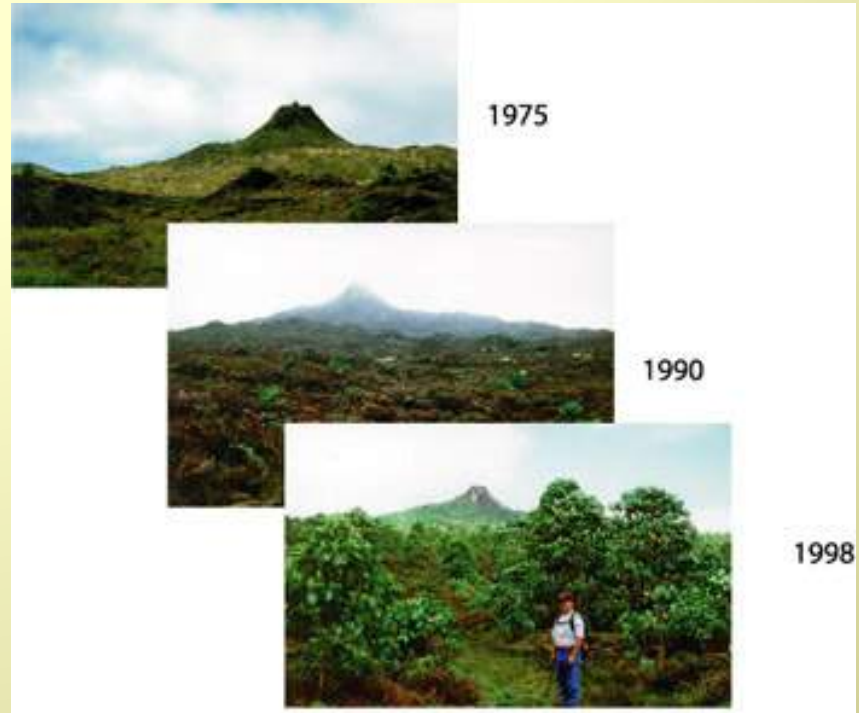
Table 2 Original introductions that have resulted in the present vascular plant flora of the Galapagos Islands

Introduced	Birds	Man	Wind	Oceanic drift	Total
Pteridophytes	1		86		87
Monocotyledons	58	38	14	2	112
Dicotyledons	166	143	18	33	360
Total	225 (40%)	181 (32%)	118 (21%)	35 (6%)	559
Total for natural introductions	225 (60%)		118 (31%)	35 (9%)	378

Galapagos Flora

Humans, islands, and exotics

- invasives (quinine, guava, grasses, dutchman's pipe)
- humans, exotics, and islands go hand in hand



Cinchona (quinine) on Santa Cruz

Table 2 Original introductions that have resulted in the present vascular plant flora of the Galapagos Islands

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Galapagos Flora

Julie Denslow
USDA Forest Service, Institute for Pacific Islands Forestry

"Weeds in Paradise"

another principle of Island Biology

WEEDS IN PARADISE: THOUGHTS ON THE INVASIBILITY OF TROPICAL ISLANDS[1]

Julie S. Denslow[2]

ABSTRACT

Tropical island ecosystems appear to be especially vulnerable to invasive species as indicated by the often high numbers and percentages of exotic species on oceanic and continental islands. Here I reexamine hypotheses offered to account for the apparently high invasibility of tropical islands and suggest a simple synthesis based on resource availability, propagule supply, and relative competitive abilities of exotic and island species. This review suggests that fundamentally two interacting processes—high net resource availability and poor ability of native species to preempt those resources—make island communities vulnerable to the establishment and spread of alien species. In addition, historically high rates of introduction have provided opportunity in the form of a diverse and abundant propagule rain of exotic species. The combination produces a scenario that is not an optimistic one for island ecosystems. It suggests that these native ecosystems on islands are particularly vulnerable to naturalizing exotics growing on their borders, and that while disturbance from a variety of causes, including pigs, fire, grazing, and natural dieback of the canopy dominants, increases the opportunities for exotic incursions, even intact forests are not immune. Unless these forests are aggressively managed and alien propagule pressure reduced, they will be highly modified by expanding exotic plant populations. Tropical islands are an effective early warning system of the impacts that successive waves of exotic species invasions may cause to isolated ecosystems. As mainland natural areas become fragmented, degraded and depauperate, they acquire many of the ecological attributes of islands, including limited habitat area, missing functional groups, declining species diversity, and disturbed habitats. A better understanding of invasions on islands may improve our attempts to protect both mainland and island ecosystems from the impacts of exotic species.

Key words: alien species, exotic species, extinctions, invasive species, invasibility, island ecosystems, plant communities, tropical islands.

Galapagos Flora

How did the original colonists get there?

- 378 original colonists (gave rise to 522 native species)
- 60% of original colonists via bird LDD
- 31% and 9% via wind and sea drift, respectively

endemic *Lecocarpus* – 3 species

Table 2 Original introductions that have resulted in the present vascular plant flora of the Galapagos Islands

Introduced	Birds	~~Man~~	Wind	Oceanic drift	Total
Pteridophytes	1		86		87
Monocotyledons	58	~~38~~	14	2	112
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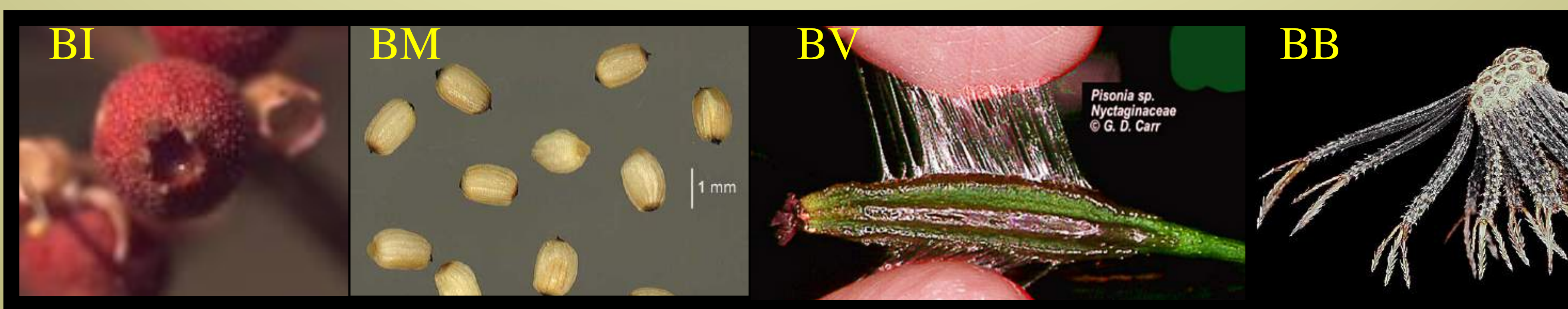
Total for natural introductions	225 (60%)		118 (31%)	35 (9%)	378

Galapagos Flora

How did the original colonists get there?

• different bird dispersal mechanisms for 225 bird-dispersed colonists

64%	BI	internal digestive system
15%	BM	mud attached to birds
12%	BV	attached by viscid structures of seeds/fruits
8%	BB	attached mechanically by barbs/hooks



LDD to Island Systems

Types of long distance dispersal

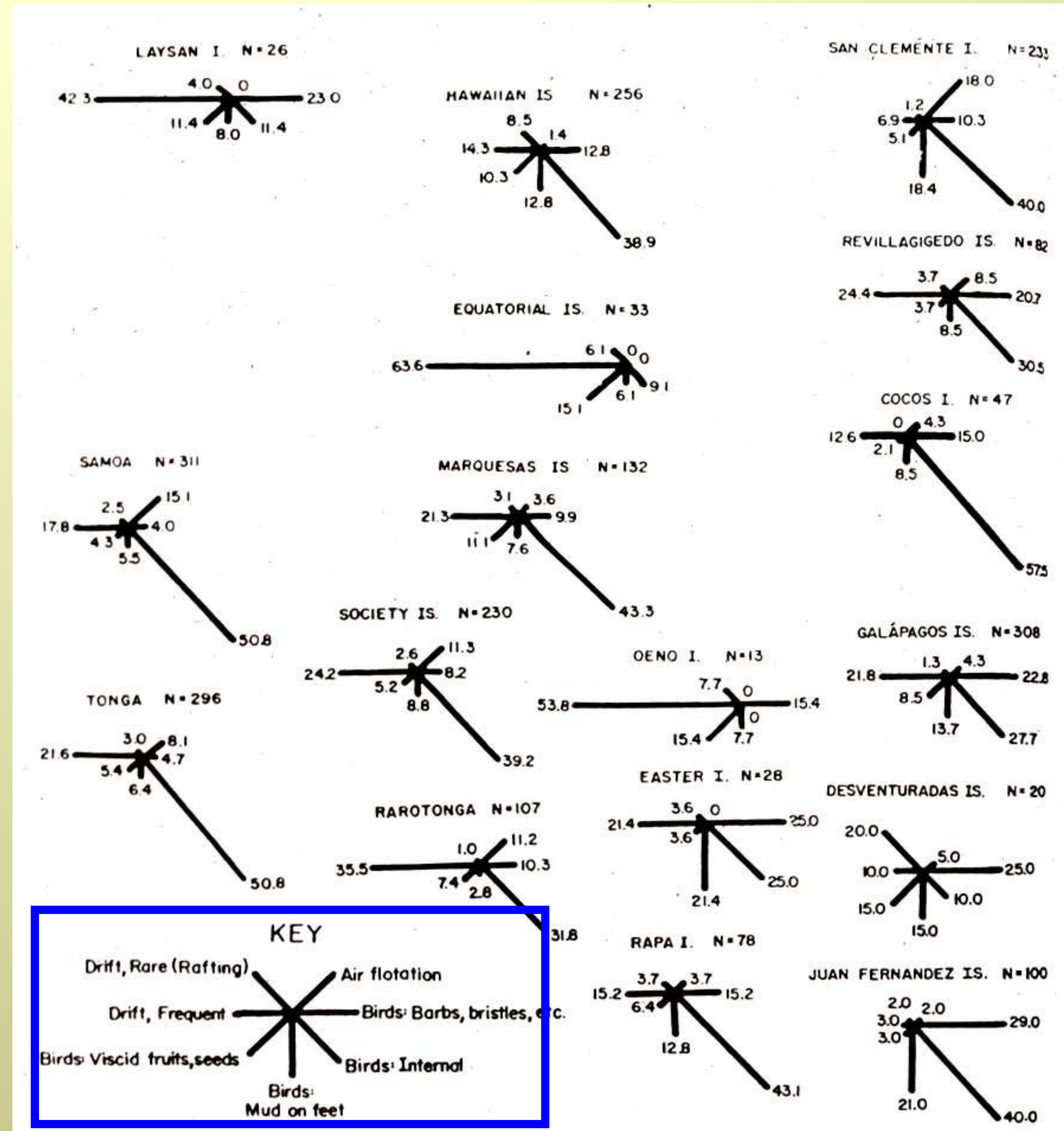
A	air or wind flotation
BI	internal digestive system
BM	mud attached to birds
BV	attached by viscid structures of seeds/fruits
BB	attached mechanically by barbs/hooks
DF	oceanic drift - frequent
DF	oceanic drift - rare or rafting

LDD to Island Systems

Patterns of long distance dispersal

• distance and ecology of islands very important in determining which LDD method operates

• see Principle #8 from *Principles of Dispersal and Evolution on Islands* (Carlquist, 1974)



LDD to Island Systems

Patterns of long distance dispersal

• atoll islands are only mid-ocean beaches
- drift plants predominate

Comparisons of Pacific islands with respect to dispersal types

Dispersal type	*Hawaiian Islands*	*Samoa*	*Lowest Percentage*	*Highest Percentage*
A	1.4	15.1	0 (Eq. atolls)	18.0 (San Clemente I.)
BB	12.8	4.0	0 (Eq. atolls)	29.0 (J. Fernandez Is.)
BI	38.9	50.8	0 (Oeno I.)	50.8 (Samoa, Tonga)
BM	12.8	5.5	2.8 (Rarotonga)	21.0 (J. Fernandez Is.)
BV	10.3	4.3	2.1 (Cocos Is.)	15.4 (Oeno I.)
DF	14.3	17.8	3.0 (J. Fernandez Is.)	63.6 (Eq. atolls)
DR	8.5	3.5	0 (Cocos Is.)	8.5 (Hawaii)

LDD to Island Systems

Patterns of long distance dispersal

- remote islands low in air flotation since it operates poorly across long distances - such as Hawaii

Comparisons of Pacific islands with respect to dispersal types

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LDD to Island Systems

Patterns of long distance dispersal

- wind dispersal effective for short distances *for most plants*

May 2003 WIND DISPERSAL POTENTIAL IN PLANTS

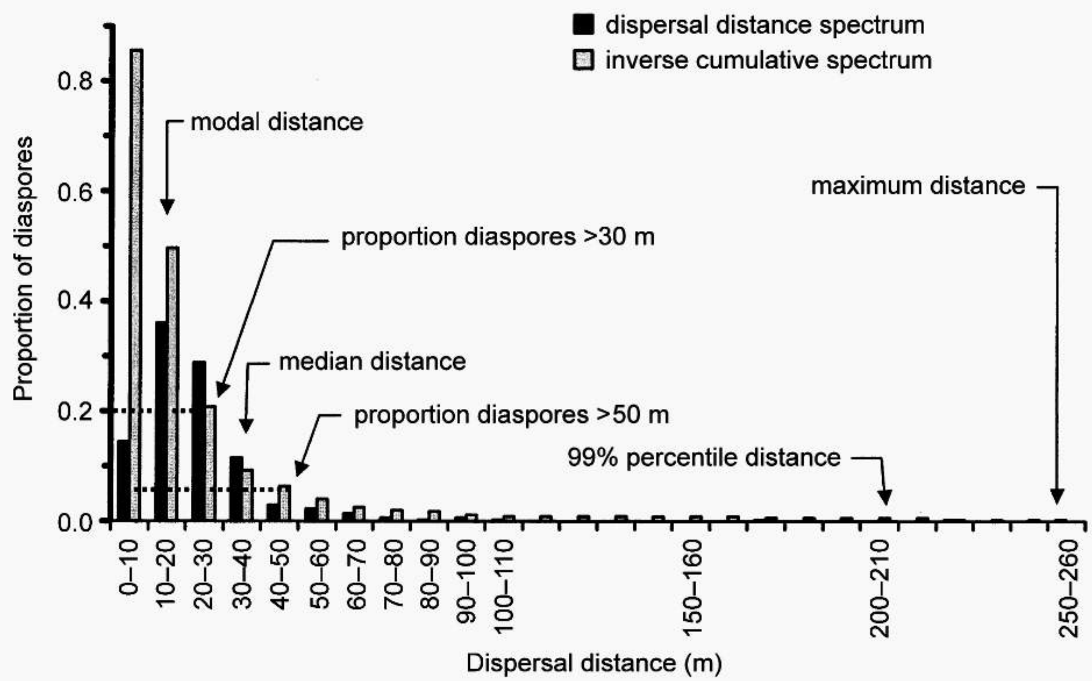

FIG. 1. Hypothetical dispersal distance spectrum showing frequency distributions of dispersal distances, and some possible measures of the dispersal potential. The inverse cumulative spectrum shows the proportion of diaspores exceeding the respective distance.

Ecological Monographs 73:191-205

LDD to Island Systems

Patterns of long distance dispersal

• but air flotation is high on near islands such as San Clemente off of western North America

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LDD to Island Systems

Patterns of long distance dispersal

• bristly fruits correlated with dry forested islands such as Juan Fernandez Islands, or where birds are very active

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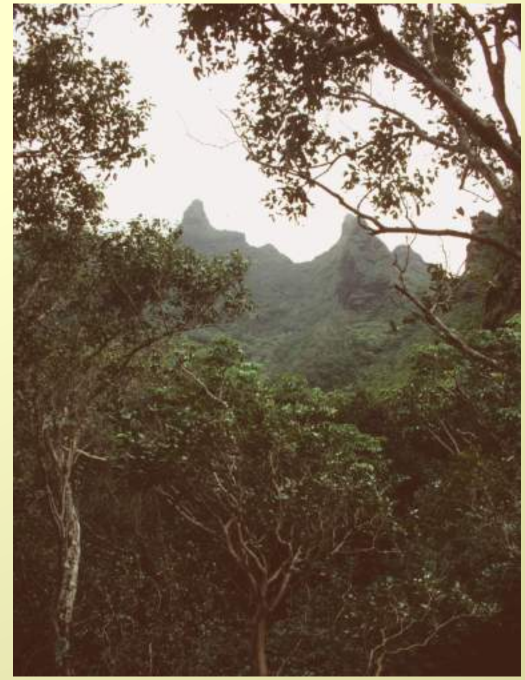
LDD to Island Systems



Patterns of long distance dispersal

• fleshy fruits correlated with wet forested, montane islands (Samoa, Tonga) - effective LDD method as found in remote islands (Hawaii)

Comparisons of Pacific islands with respect to dispersal types

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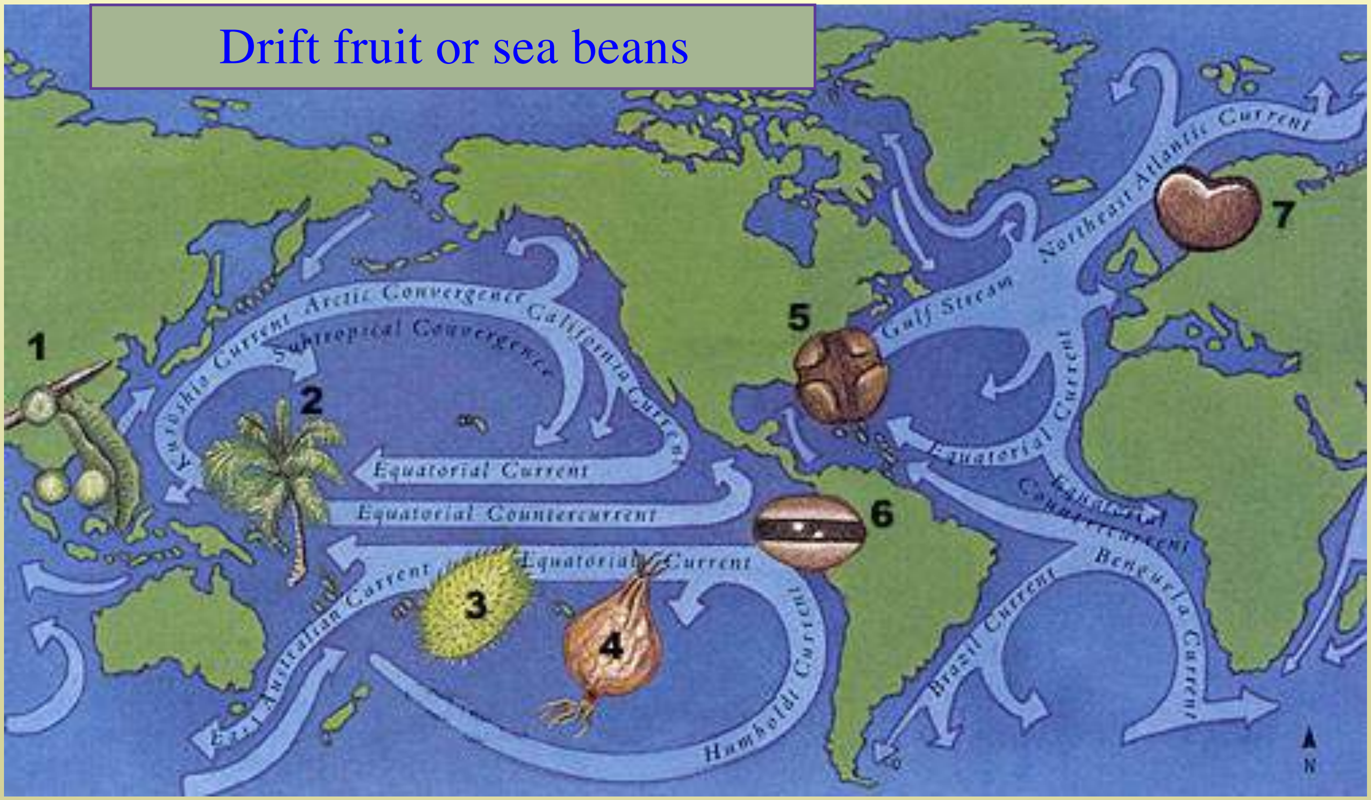
LDD to Island Systems

Final thoughts - 1. dispersal does not = establishment!



1. Tamanu (*Calophyllum inophyllum*), Indonesia to the Philippines.
2. Coconut (*Cocos nucifera*), Melanesia to Eastern Australia.
3. Nickernut (*Caesalpinia bonduc*), Tropical America to Canton Island.
4. Box Fruit (*Barringtonia asiatica*), Islands of Micronesia to Tahiti.
5. Mary's Bean (*Merremia discoidesperma*), Central America to Florida.
6. Sea Bean (*Mucuna sloanei*), Tropical America to Galapagos Islands.
7. Sea Heart (*Entada gigas*), Tropical America to Mexico and Europe.

LDD to Island Systems

Final thoughts - 1. dispersal does not = establishment!

- *Mucuna* - American tropical legumes regularly disperse to Hawaiian beaches, *but seldom have established*

- Principle # 5 - elements present in proportion to both ability to disperse and establish (ecology of island)

LDD to Island Systems

Final thoughts - 2. “disharmony” in flora is evidence for LDD

• Hawaiian flora composition (families and genera) is strikingly different than that found on mainlands

• Filter allows selective families, genera, species for LDD - island flora not in harmony with source area flora or disharmonic

• Principle # 1 – disharmony in island flora composition is evidence of LDD