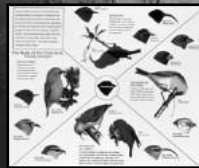


Biogeography of Islands

'Insular Syndrome' 24 principles

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



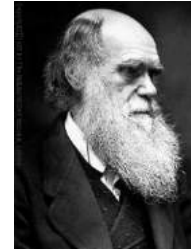
Adaptive radiations



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 transport, 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

- 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

Problem: all sunk to bottom of vials!



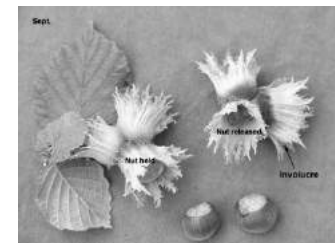
Dispersal Biology



- 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

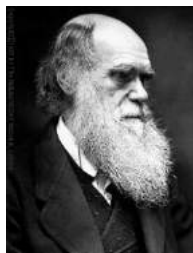
- suspended duck feet in aquarium stocked with freshwater snails



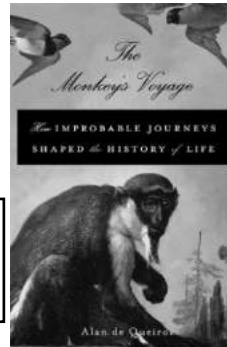
- molluscs crawled on, clung tightly in air for 12-20 hours — Darwin argued that duck or heron would have flown 700 miles

Dispersal Biology

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



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



The resurrection of oceanic dispersal in historical biogeography
Alan de Queiroz

Dispersal Biology

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

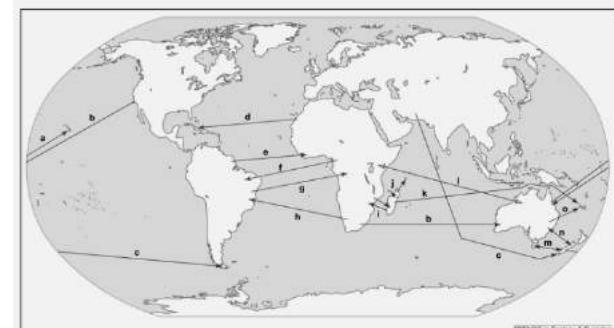
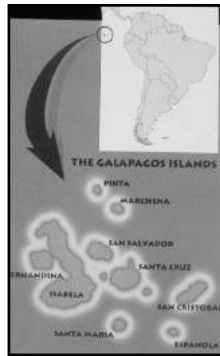


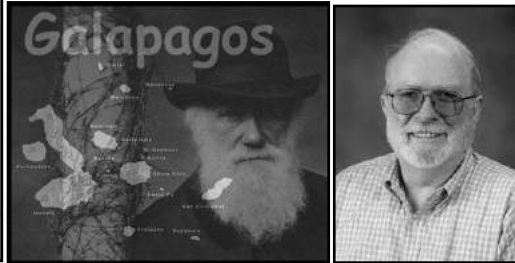
Figure 1. Striking examples of oceanic dispersal: (a) *Scaevola* (Angiosperm): Goochianaeal three times from Australia to Hawaii (18); (b) *Epilobium* mustard (Angiosperm): Bromeliaceae from North America and Africa to Australia (18); (c) *Myosotis* forget-me-nots (Angiosperm): Borealiaceae from Eurasia to New Zealand and from New Zealand to South America (21); (d) *Tarenoua* geckos from Africa to Cuba (18); (e) *Mitralichnepteris* (Angiosperm): Ruprechtaceae from South America to Africa (24); (f) *Psychotria* (Psychotriaceae) from Africa to South America (18); (g) *Malvaceae* (Angiosperm): Malvaceae from South America to Africa (18); (h) *Utricularia* (Angiosperm): Malvaceae from Africa to South America (21); (i) *Chamaecrista* three times from Madagascar to Africa (19); (j) *Amelanchier* (Angiosperm): Nyctaginaceae from Madagascar to New Caledonia (22); (k) *Banksia* (Angiosperm): Boraginaceae: Adiantaceae between Africa and Australia (21); and (l) *Prokaryote* species between Tasmania and New Zealand (20); (m) *Tringa* bird line between Australia and New Zealand (18, 20, 26); and (n) *Nemertean* (Angiosperm): Adiantaceae 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

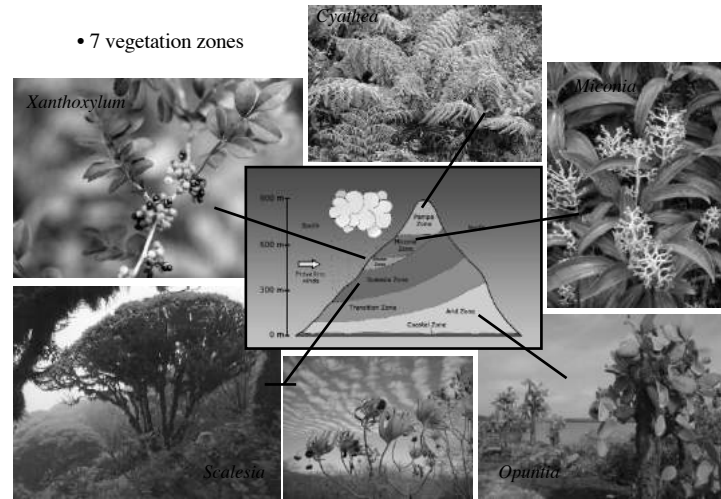


Duncan Porter 1976 "Geography and dispersal of Galapagos Islands vascular plants" Nature 264:745-746



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
Pteridophytes	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

Introduced	Birds	Man	Wind	Oceanic drift	Total
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Galapagos Flora



Julie Denslow
USDA Forest Service, Institute for
Pacific Islands Forestry

WEEDS IN PARADISE:
THOUGHTS ON THE
INVASIBILITY OF
TROPICAL ISLANDS*

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 non-reef and non-reef islands. Here I examine the hypothesis offered to account for the apparently high invasibility of tropical islands and suggest a simple synthesis based on resource availability, geographic aspects, and relative competitive abilities of exotic and island species. This review suggests that biologically less interesting processes—high sea resource availability and good ability of native species to prevent those resources—make island communities vulnerable to the establishment and spread of alien species. In addition, biologically high rates of invasions have proceeded, apparently in the form of a ratchet andatchet process, rate of exotic species. The evolutionary process is a scenario that is not an optimum one for island ecosystems. It suggests that these native communities on islands are particularly vulnerable to invading species, growing on their borders, and that while disturbance from a variety of causes, including gaps, fires, storms, and natural death of the canopy dominates, invasion, the opportunities for exotic invasions, even from flowers, are not unusual. Unless these forests are aggressively managed and alien propagule pressure reduced, they will be highly modified for expanding exotic plant populations. Tropical islands are an effective early warning system of the impacts that successive waves of exotic species invasions may cause in isolated ecosystems. An isolated natural area, between fragmented, degraded and disappearing, they are given many of the ecological attributes of islands, including limited habitat area, existing functional groups, discrete species diversity, and distinct isolation. A better understanding of resources on islands may suggest one strategy to control both natural and alien invasions from the impacts of exotic species.

Key words: alien species, exotic species, invasions, resource species, invasibility, island ecosystems, plant communities, tropical islands.

"Weeds in Paradise"

another principle of
Island Biology

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



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

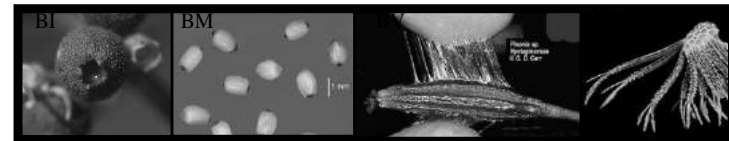
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Galapagos Flora

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

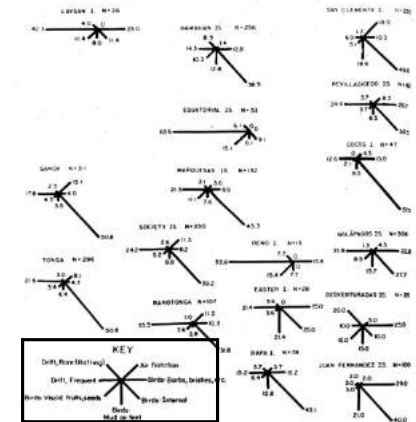
- A air or wind flotation
- BI internal digestive system
- BM mud attached to birds
- BV attached by viscid structures of seeds/fruits
- BB attached mechanically by barbs/hooks
- DF oceanic drift - frequent
- DR oceanic drift - rare or rafting



LDD to Island Systems

Patterns of long distance dispersal

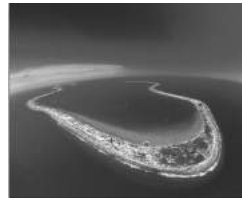
- distance and ecology of islands very important in determining which LDD method operates
- see Principle #8 from *Principles of Dispersal and Evolution on Islands* (Carlquist, 1974)



LDD to Island Systems

Patterns of long distance dispersal

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



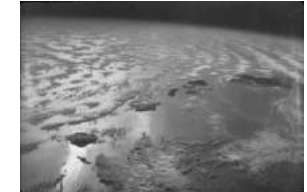
Comparisons of Pacific islands with respect to dispersal types

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



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LDD to Island Systems

Patterns of long distance dispersal

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

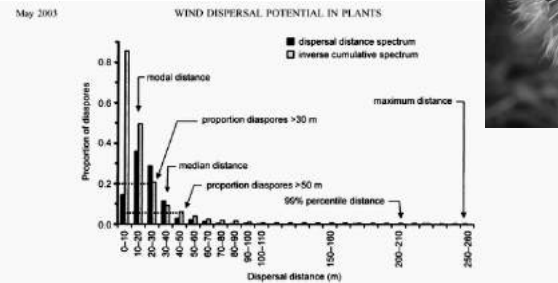


FIG. 1. Hypothetical dispersal distance spectrum showing frequency distributions of dispersal distances, and some possible measures of the dispersal potential. The inverse cumulative spectrum shows the proportion of diaspores exceeding the respective distance.

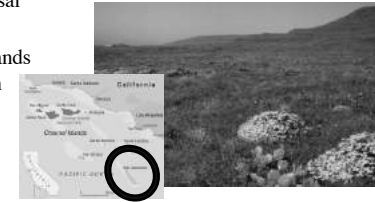
Ecological Monographs 73:191-205



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



Comparisons of Pacific islands with respect to dispersal types

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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)

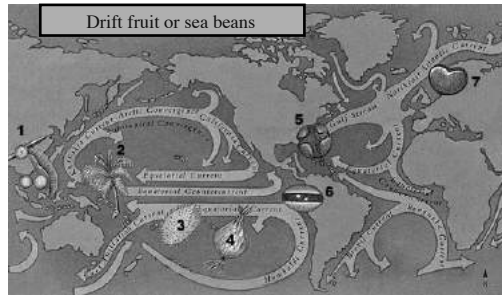


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LDD to Island Systems

Final thoughts - 1. dispersal does not = establishment!



1. Tamaru (*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