Lessons from ecology for the future of Puerto Rico: Implications for land and resource use

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Health Care Crisis

"We don't want bureaucrats in insurance companies making decisions about our health."

Ecologists need to join the discussion about resource use.

Outline for today

- Big Ecology = Big Issues
  - Biodiversity
  - Meat production
  - Economic growth
- Local Ecology = Local Issues
  - Wind energy in Puerto Rico

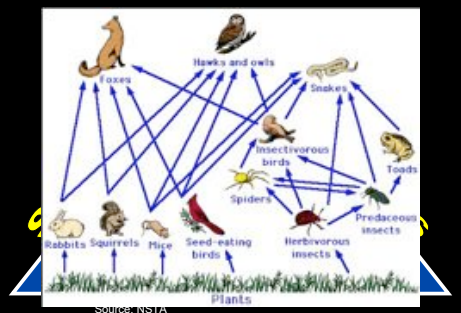
Fundamentals of Ecology (and Physics)

- Entropy and Trophic dynamics
- Competitive Exclusion
- Island Biogeography
- Law of the Minimum and Carrying Capacity

Entropy & Production Efficiency

- Nature moves from order to disorder
  - Disorder frequently means heat loss
- The proportion of energy that is converted into new biomass

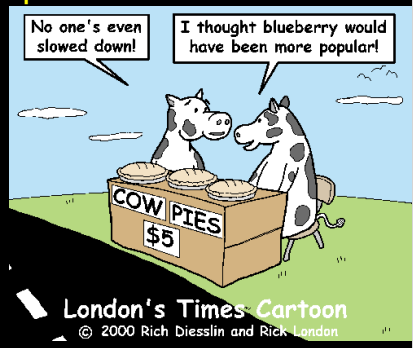
Trophic Structure



Source: NSTA

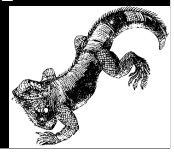
Trophic efficiencies

At each level, more energy is lost to maintenance, less energy is used to create biomass.



Production Efficiencies

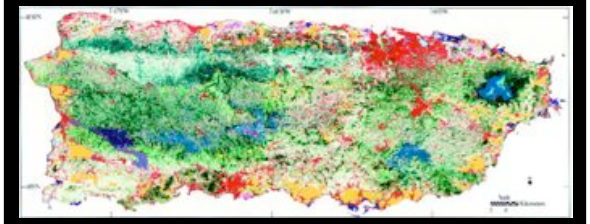
Animal types	Production Efficiency (%)
Insects	30-40
Cold-blooded vertebrates	10
Mammals and birds	1-2



Competitive Exclusion

- No two species can occupy the same niche. In these cases, the superior competitor eliminates the inferior competitor.

What is human's niche?



Island Biogeography: Larger islands and those closer to migrant sources will have greater biodiversity

Forest fragments are islands

Cutting up forests decreases habitat, decreases the amount of space and resources for species.

Endangerment Causes

Urbanization	247
Agriculture	205
Water diversions (e.g., reservoirs)	160
Recreation, tourism development	148
Pollution	143
Domestic livestock, ranching	136

Czech et al. 2000. *Bioscience* 50(7):593-601.

These are the top 6 causes of species endangerment on the mainland United States, and the next slides shows the next 6 causes. [Flip back and forth between these two slides a couple of times while using the following narrative.] The causes are listed in the left-hand column, with the number of species listed as threatened or endangered (pursuant to the Endangered Species Act) in the right-hand column. The list of causes includes the proliferation of the labor force, light manufacturing, and service sectors (urbanization), the agro-extractive sectors (agriculture, livestock ranching, mining, and direct harvest of individual animals (logging is # 13 and just off the list)), economic infrastructure (reservoirs, roads), economic byproduct (pollution), a service sector with direct impact on species (outdoor recreation), manufacturing sectors (industrialization), incidental effects (modified fire regimes), and invasive species, a function of international trade and interstate commerce.

More Causes

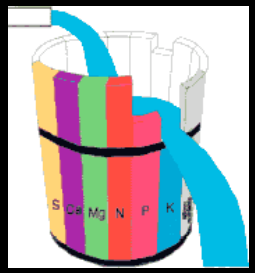
Mineral, gas, oil extraction	134
Non-native species	115
Harvest	101
Modified fire regimes	83
Road construction/maintenance	83
Industrial development	81

Czech et al. 2000. *Bioscience* 50(7):593-601.

Law of the Minimum

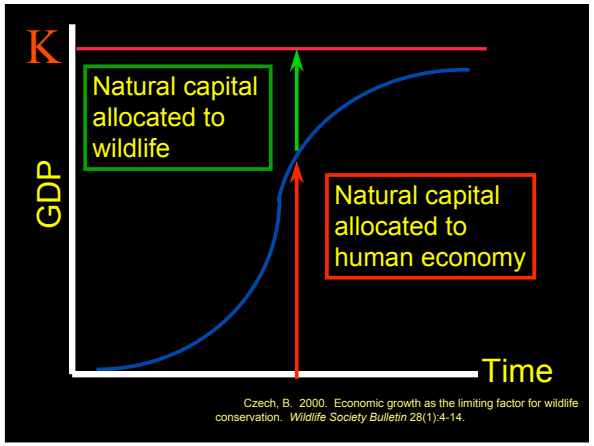
Population growth will continue until it becomes limited by the resource in the shortest supply

- N, P, K, Water, etc.



Carrying Capacity

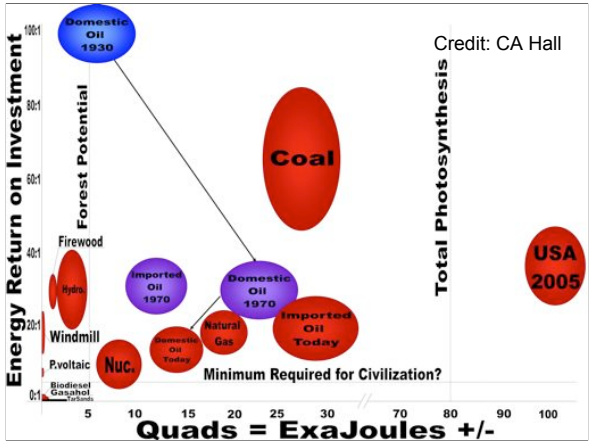
- The maximum number of individuals that resources in a given area can support
- The given area for human societies has expanded to fill the globe



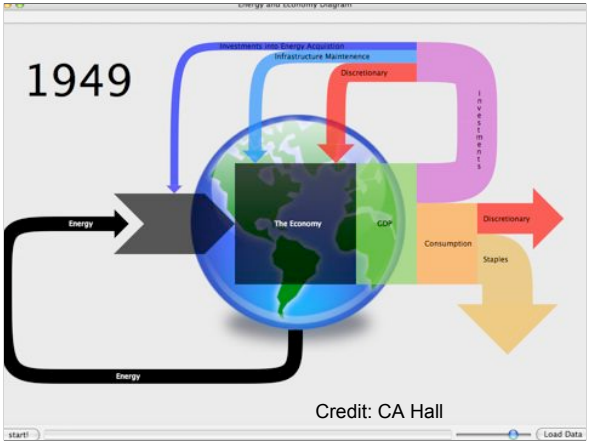
Here we see the economy, its size gauged by GDP, growing in sigmoid fashion toward carrying capacity (K). This growth is a process of reallocating natural capital (such as soil, water, timber, and minerals) from the "economy of nature" with its non-human species to the human economy, where the natural capital is converted into manufactured capital and consumer goods. This process may be summarized in one sentence: "Due to the tremendous breadth of the human niche, the human economy grows at the competitive exclusion of wildlife in the aggregate."

What will limit human populations and human economies?

- Land?
- Water?
- Oil?
- Money?



Credit: CA Hall



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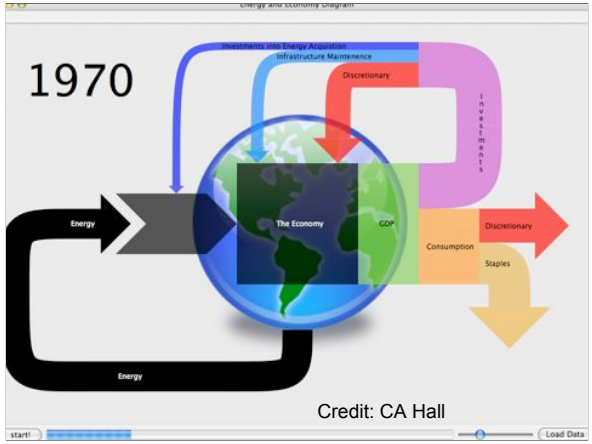

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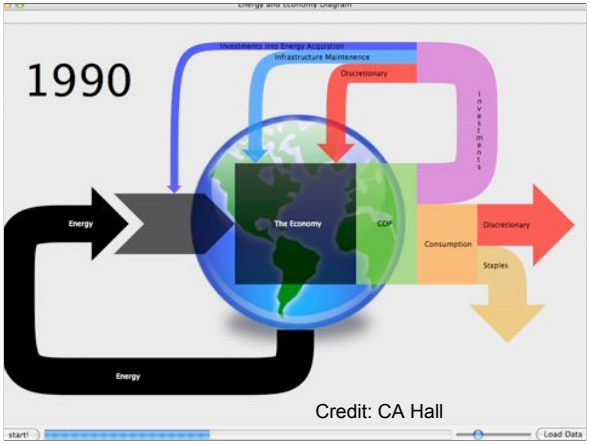

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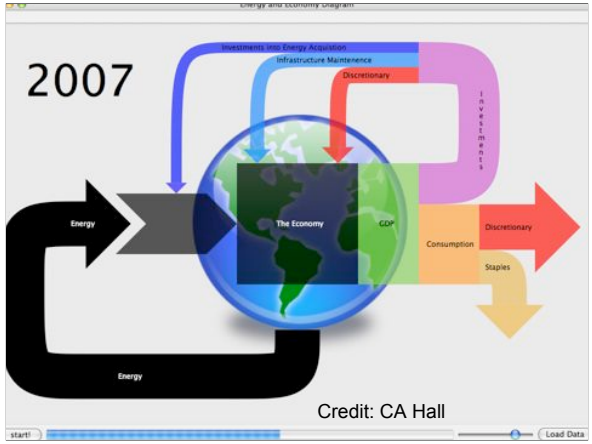

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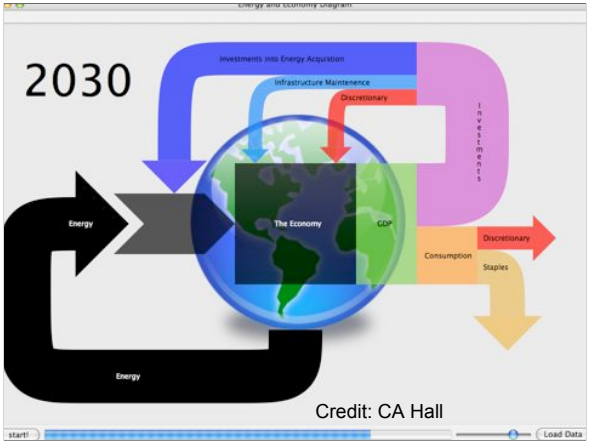

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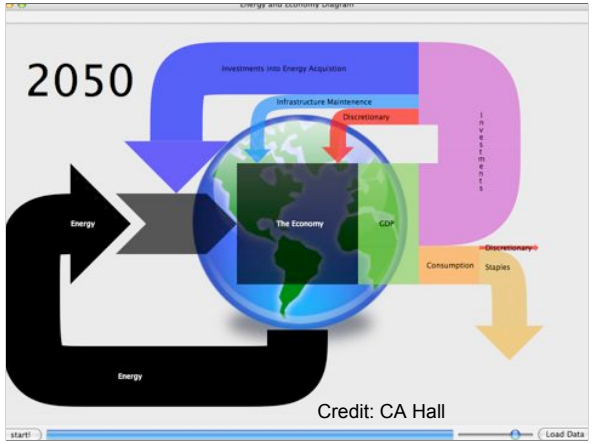

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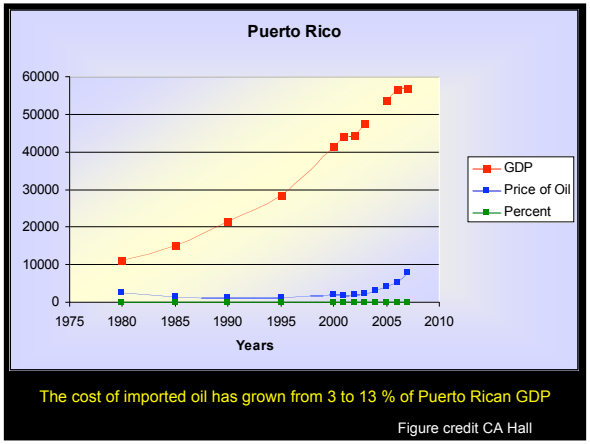


The cost of imported oil has grown from 3 to 13 % of Puerto Rican GDP

Figure credit CA Hall

Economic Growth

- an increase in the production and consumption of goods and services
- typically expressed in terms of GDP
- facilitated by increasing:
  - population
  - per capita consumption

Let's begin with the standard definition of economic growth. Economic growth is simply an increase in the production and consumption of goods and services. It is typically gauged by gross domestic product, or "GDP." GDP is not a reliable indicator of human **welfare**, but only of the **size** of the economy. Furthermore, GDP is an **indicator**, not a precise measure, of the size of the economy. Economic growth, per se, is an increase in the production and consumption of goods and services and is facilitated by increasing population and per capita consumption.

The Great Debate: **Is There a Limit?**

"Yes"	"No"
• Physiocrats	• Neoclassical economists
• Classical economists	• Corporations
• Ecological economists	• Politicians
• Ecologists	

"The Great Debate" is somewhat of a misnomer, because the physiocrats ("les economistes," the prototypical economists of 18th century France) and the classical economists of the 19th century left no doubt that there were limits to economic growth. In fact, limits to growth were central to the works of Thomas Malthus, David Ricardo, and John Stuart Mill. Today's "neoclassical economists," however, along with the corporate and political communities, often claim there is no limit to economic growth. Ecological economists and ecologists in general, on the other hand, claim there is.

Why would there not be a limit?

- Substitutability of resources
- Increasing productive efficiency

The argument given by neoclassical economists and others touting perpetual economic growth is based upon the substitutability of resources and increasing productive efficiency stemming from technological progress.

Why would there be a limit?

- Carrying capacity
- Thermodynamics
- Trophic levels

Ecologists and ecological economists base their argument for limits to growth upon laws of thermodynamics and trophic theory. Limits to growth are so fundamental that carrying capacity itself is considered a core concept in ecology.

But what about

Technological Progress?

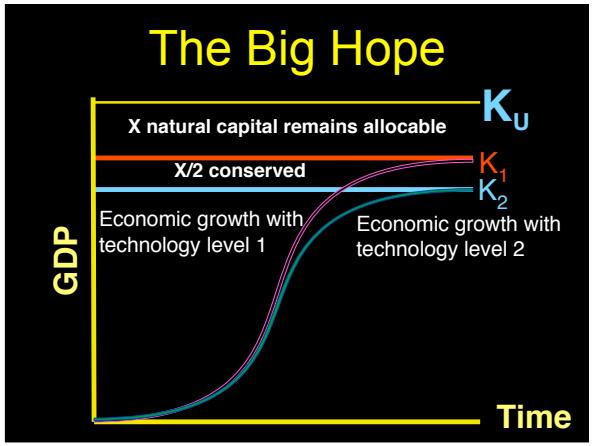
Those inclined to question the necessity of a steady state economy for wildlife conservation will invariably ask, “But what about technological progress?”

Consider the Sources of Technological Progress

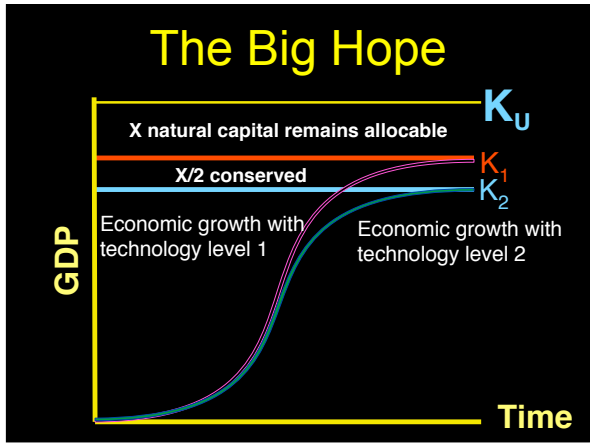
- Research and development
- Corporate profit

Czech, B. 2003. *Conservation Biology* 17(5):1455-1457.

In other words, R&D funds require profits, or income above what is required purely for subsistence, wages, and maintenance of capital depreciation. Economists of all ilks agree, however, that profits dry up in competitive, capitalist economies, except for firms that become more efficient (via technological progress) than competitors. This sets up a Catch-22: technological progress is required for profits, but profits are required for technological progress.



The big hope for technological progress is that, as technology proceeds from level 1 to level 2, it does so via the conservation of natural capital, thus leaving the original "X" amount of natural capital allocable entirely to nonhuman species. If this were a fundamental reality that continually applied, then it would imply that there is no limit to economic growth, and no limit to the universal, human-inclusive economy of nature. We could have a $40 trillion global economy with the current level of biodiversity, or a $400 trillion economy with the same level of biodiversity. This brings up the question about limits to economic growth.



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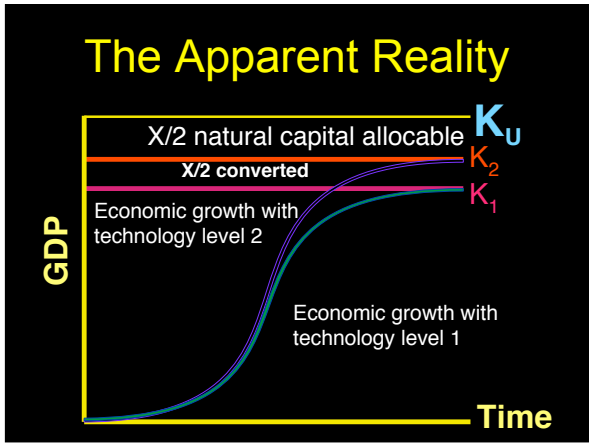


The big hope is not realized because the chicken-egg spiral of economic growth and technological progress entails the continual reallocation of natural capital from the economy of nature to the human economy.

Steady State Economy

- Stable production and consumption of goods and services
- Indicated by stable GDP
- Stabilized:
  - population
  - per capita consumption
  - "throughput"

The steady state economy is simply a non-growing, non-declining economy, with stabilized (or mildly fluctuating) production and consumption of goods and services. It is indicated by stable GDP. It consists of a stabilized population, per capita consumption, and "throughput," or the amount of energy and materials used in the production process. By definition (to be stable) it occurs at a size whereby renewable natural resources are harvested at sustainable rates, and non-renewable resources are gradually weaned from the system.

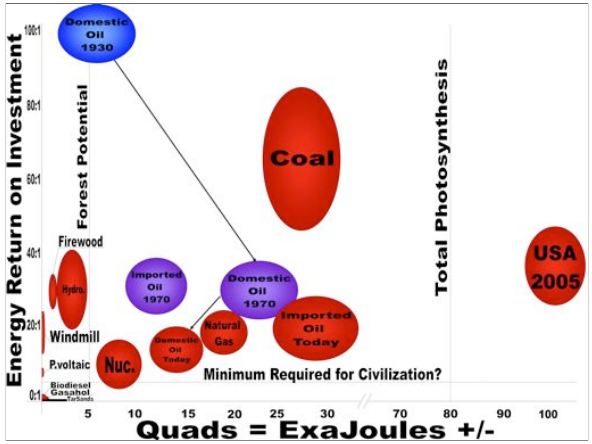
Quality of Life

- Steady in a material sense
- Increasing in a holistic sense
- Sustainable
- Ever higher relative to quality in bloating economy

While physical growth ceases in a steady state economy, economic development may yet occur, where development is defined in qualitative terms. For example, some sectors may wax (for example, wildlife biology) while some may wane (for example, NASCAR). Perhaps the main point in comparing the quality of life in a growing economy vs. a steady state is that, relative to the steady state, the quality of life in a bloating economy (i.e., an economy beyond carrying capacity) continually declines as the economy becomes less stable and produces the "supply shocks" and disasters that characterize an economy beyond carrying capacity.

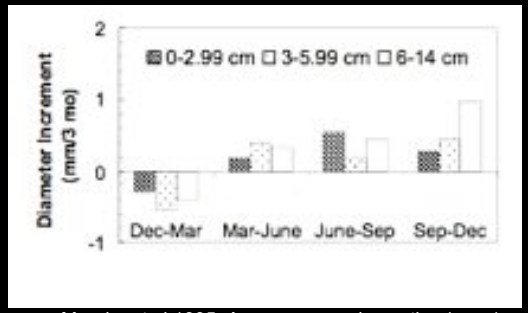
Local Ecology: Wind Farm Development in Guayanilla

WindMar Inc. Victor Gonzalez



- *Mature* Krugiodendron ferreum, Coccoloba diversifolia, Pictetia aculeata, *and* Gymnanthes lucida *should have easily exceeded [6-7 cm diameter]. It is as if, about a half century ago, the WindMar property was deforested to a high degree, and only since then has this dry forest had a chance to recover.*
- *También resulta curioso el tamaño de los árboles. A excepción de los Almácigos (Bursera simaruba) y Corcho Bobos de rápido crecimiento (Pisonia albida), cuyos troncos pueden llegar al pie de diámetro en área estudiada, la inmensa mayoría de los árboles de madura dura no llegan a alcanzar allí los 6-7 cm de diámetro basal.*

Seasonal growth rates of trees in Guánica Forest



Source: Murphy et al 1995 Average annual growth <1 mm/y

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Land Cover in the Wind Farm Area

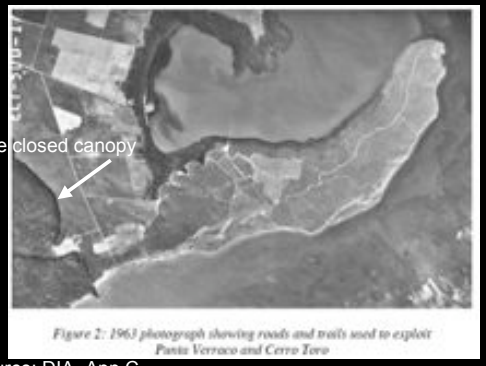
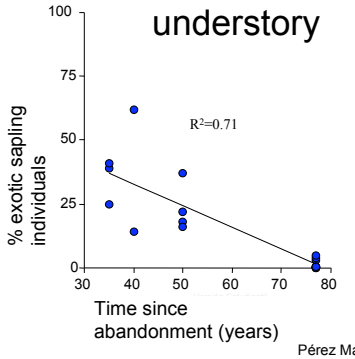


Figure 2: 1963 photograph showing roads and trails used to exploit Punta Verraco and Cerro Toro

Source: DIA. App C.

Prevalence of exotics in understory



Pérez Martínez & Van Bloem 2008

Parque Eolica

En cambio muchas otras especies tienen la capacidad de rebrotar desde el tocón para producir formas multicaules o "parasoles" que por lo común no aparecen espontáneamente en la naturaleza. [no citation]

Estos parasoles se distinguen muy bien de los rebrotes originados en troncos derribados por vientos huracanados (éstos últimos se disponen en fila). [no citation]

Post-hurricane sprouting

	% Sprouting Stems	Sprouts per Stem
Pre-hurricane		
All trees	**4**	**2**
Post-hurricane		
Defoliated	**32**	**10**
No visible damage	**29**	**6**

Thus hurricanes cause multi-stemmed trees
Van Bloem et al 2003

*Stems with defoliation but no stem breakage or uprooting

Explain slide:

Sprout increased on numbers of stems and sprouts per stem

Note that sprouting increased substantially after the hurricane.

We would expect this on strained trees (often trees sprout after snapping).

But many trees that weren't strained also sprouted, which explains the trend in the previous slide.

This explains density and multiple stemmed physiognomy.

COMPARED TO ELSEWHERE:

WALKER 1991 LUQUILLO—9.1% OF UPRIGHT STEMS SPROUTED.

IMBERT ET AL 1998—GUADELOUPE—50% OF NEW RECRUITS FROM SPROUTS.

Finally, sprouts have survived. Only 15% mortality after 2 years.

Do little sprouts make multi-stemmed trees?

Note shrubby trees

For hurricanes to be responsible for sprouting and multiple stemmed trees, we need three things to happen

1. Sprouts must occur at or near the base of trees
2. Sprouts must occur with great frequency only after hurricanes
3. Sprouts must survive.

Parque Eolica de WindMar

Figure 2: 1963 photograph showing roads and trails used to exploit Punta Verraco and Cerro Toro

Source: DIA-P. App C.

Site of single fire in 1981

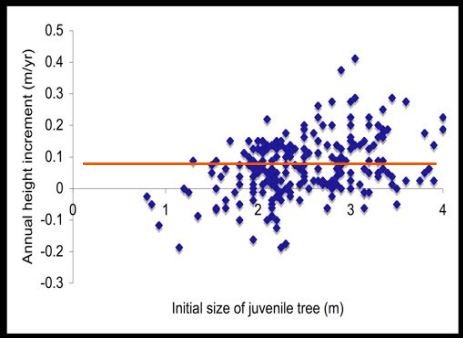
Site of a 1991 Fire

Reforestation Plan

- 5 years will have a canopy 3 to 3.5 m tall
- 10 years will have a canopy 4.5 to 5.0 m tall
- First phase “pioneers”, red lines are not pioneers

Bourreria succulenta	*Bourreria virgata*	*Bursera simaruba*
Capparis cynophallophora	*Capparis flexuosa*	*Clerodendron aculeatum*
Coccoloba microstachya	*Colubrina arborescens*	*Comocladia dodonaea*
Corchorus hirsutus†	*Croton discolor*†	*Croton lucidus*†
Erythroxylum areolatum	*Ficus citrifolia*	*Guettardia elliptica*
Guettardia krugii	*Gymnanthes lucida*	*Jacquinia armillaris*
Krameria ixine††	*Lantana involucrata*†	*Leucaena leucocephala*†††
Melochia tomentosa†	*Pictetia aculeata*	*Pisonia albida*
Pithecellobium unguis-cati	*Randia aculeata*	*Reynosia uncinata*

Annual Height growth of 240 Saplings in Guánica Forest



Conclusions -- WindMar

- Rudimentary understanding of PR dry forest ecology (AT BEST)
- EIS either represents bad science or intentional misinterpretation to serve Windmar
- Long term data refutes claims
- Wind power at all costs is not worth it
- Return on investment is low

- Thanks to Charlie Hall and Brian Czech for providing slides and figures.
- Thanks to MAC for the invitation to speak to you today.