Forest Conservation Biology

- Objectives:
  - Overview of Conservation Biology
    - Biodiversity
      - What is it?
      - Why is it important?
      - What are the threats to biodiversity?
    - Forest Conservation Management

*Parts of this lecture were adapted from online materials provided by the Network of Conservation Educators and Practitioners, Center for Biodiversity and Conservation, American Museum of Natural Heritage (http://ncep.amnh.org/index.php?globalnav=home&sectionnav=home).

Forest Conservation Biology

- Warm-up Questions:
  - What is conservation biology? How does it differ from biological conservation? Restoration ecology? Ecological restoration?
  - What is biodiversity? Why is biodiversity important?
  - What are the past and current threats to biodiversity?
  - How can forests be managed for conservation of biodiversity?

Forest Conservation Biology

- Terminology
  - *Conservation biology*
    - *science of analyzing and preserving existing biological diversity (i.e., biodiversity)*
      - Save it before it becomes damaged, degraded, or destroyed
      - Based on fundamental ecological and evolutionary principles
      - Conservation biology (the science) vs. biological conservation (the practice)
      - Society for Conservation Biology (www.conbio.org/)
        - » **SCB Mission:** *To advance the science and practice of conserving the Earth's biological diversity.*
      - Association of Tropical Biology & Conservation (www.tropicalbio.org/)
        - » **ATBC Mission:** *To promote research & foster the exchange of ideas among biologists working in tropical environments*.

Forest Conservation Biology

- *Conservation biology* vs. *Restoration ecology*
  - Conservation biology is to biological conservation what restoration ecology is to ecological restoration
  - "conserving what is left" *vs*. "restoring what once was"

Manukā Tropical Dry Forest Natural Area Reserve

vs.

Ka'upulehu Tropical Dry Forest Restoration

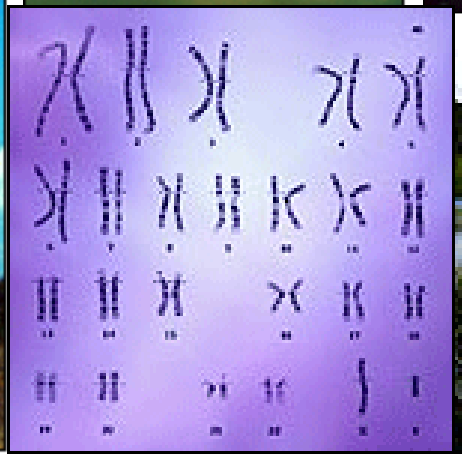
Forest Conservation Biology

- What is biodiversity?
  - Biodiversity (biological diversity) refers to the diversity in the living (biotic) component of ecological systems
  - There are several ecological *levels* of biodiversity
    - Genetic, species, population, community, ecosystem, and landscape
    - Important interactions exist between and within levels
  - Ecological and evolutionary processes are fundamental
    - Drive observed patterns in biodiversity at all levels

Forest Conservation Biology

- What is biodiversity?
  - the variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that determine and sustain it



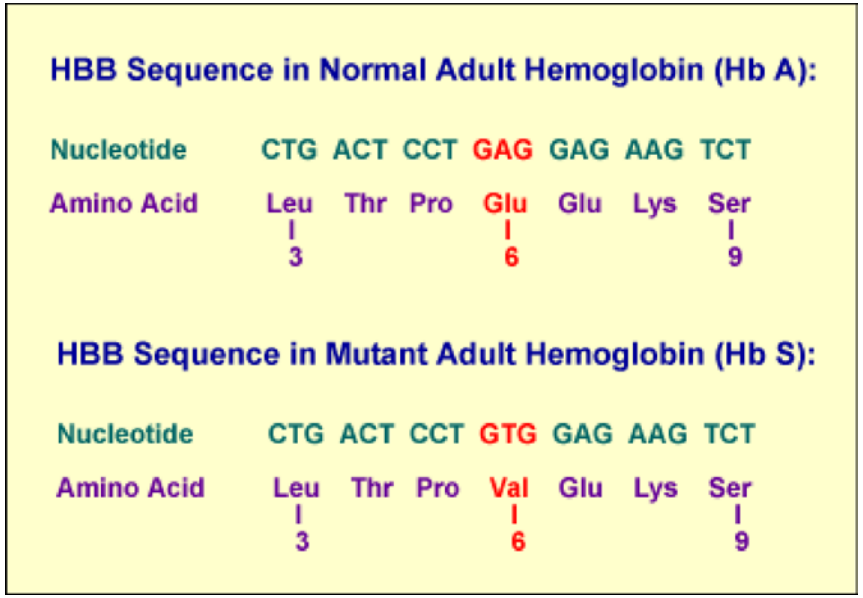

Forest Conservation Biology

- Dimensions of biodiversity

Genetic component	Spatial component	Functional component	Temporal component
within individuals	communities	e.g. reproductive behavior, predation, parasitism	daily
within populations	ecosystems		seasonal
between populations	landscapes		annual
between species	ecoregions		geological or evolutionary
	biogeographic regions		

Forest Conservation Biology

- Genetic diversity



Source: Human Genome Project, Department of Energy

"*The variation in the nucleotides, genes, chromosomes, or whole genomes of organisms*"

Forest Conservation Biology

- Genetic diversity

Source: ©AMNH-CBC

Forest Conservation Biology

- Phenotypic (morphological) diversity
  - ***Phenotype*** - the physical constitution of an organism (that results from its genetic constitution (genotype) and the action of the environment on the expression of the genes)

Phenotypic diversity refers to variation in the physical traits of organisms

Forest Conservation Biology

- Population diversity
  - Variation in the quantitative and spatial characteristics between populations

Forest Conservation Biology

- Community diversity
  - Variation in the groups of populations and species that share an environment

Forest Conservation Biology

- Ecosystem diversity
  - Variation in ecosystem types across a landscape

Tropical Dry Forest

Tropical Wet Forest

Tropical Grassland

Tropical Shrubland

Tropical Wetland

Forest Conservation Biology

- Landscape diversity
  - Variation in landscapes within a region

Forest Conservation Biology

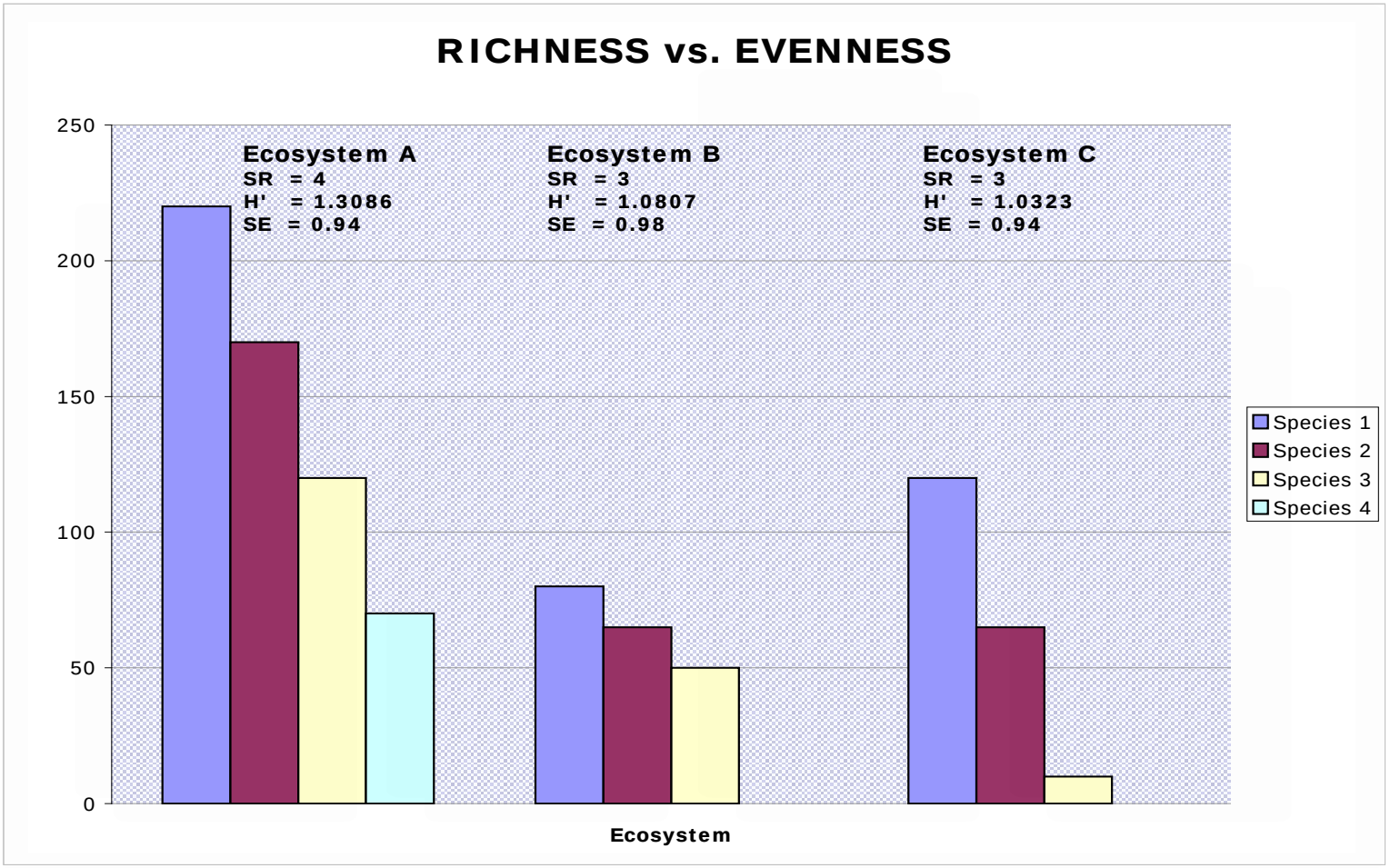
- Species diversity
  - Most common level to quantify biodiversity
  - Defined differently based on:
    - Morphological (looks)
    - Biological (sex)
    - Phylogenetics (genetics)
  - Different definitions produce different estimates of the total number of species
    - Implications for management and conservation planning?

Forest Conservation Biology

- Species diversity
  - Consists of two metrics:
    - Richness: # of species present in a given area
    - Evenness: # of species weighted by measure of importance (e.g., abundance, productivity or size)
      - Sometimes referred to as species abundance
  - Diversity Indices
    - Shannon's diversity index (H) = $-\sum \rho_i \ln \rho_i$
      - where ρ_i is the total number of individuals of species *i* expressed as a proportion of the total number of individuals of all species in the ecosystem

Forest Conservation Biology

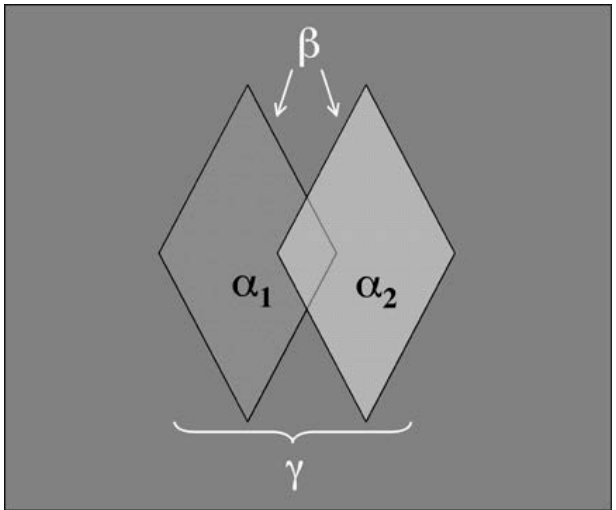
- Species diversity



Adapted from: Hunter, M. Jr. 2002. Fundamentals of Conservation Biology. 2nd Edition.

Forest Conservation Biology

- Species diversity
  - Measured differently at different spatial scales
    - **Alpha-diversity**: Measured locally, at a single site
    - **Beta-diversity**: Measures the uniqueness, or the difference between two sites
    - **Gamma-diversity**: Measured over a large scale (same concept as alpha-diversity, but larger scale)



Forest Conservation Biology

- Species diversity
  - Alpha vs. Beta vs. Gamma Diversity

Hypothetical species	Woodland habitat	Hedgerow habitat	Open field habitat
A	X		
B	X		
C	X		
D	X		
E	X		
F	X	X	
G	X	X	
H	X	X	
I	X	X	
J	X	X	
K		X	
L		X	X
M			X
N			X

Alpha diversity
Beta diversity
Gamma diversity

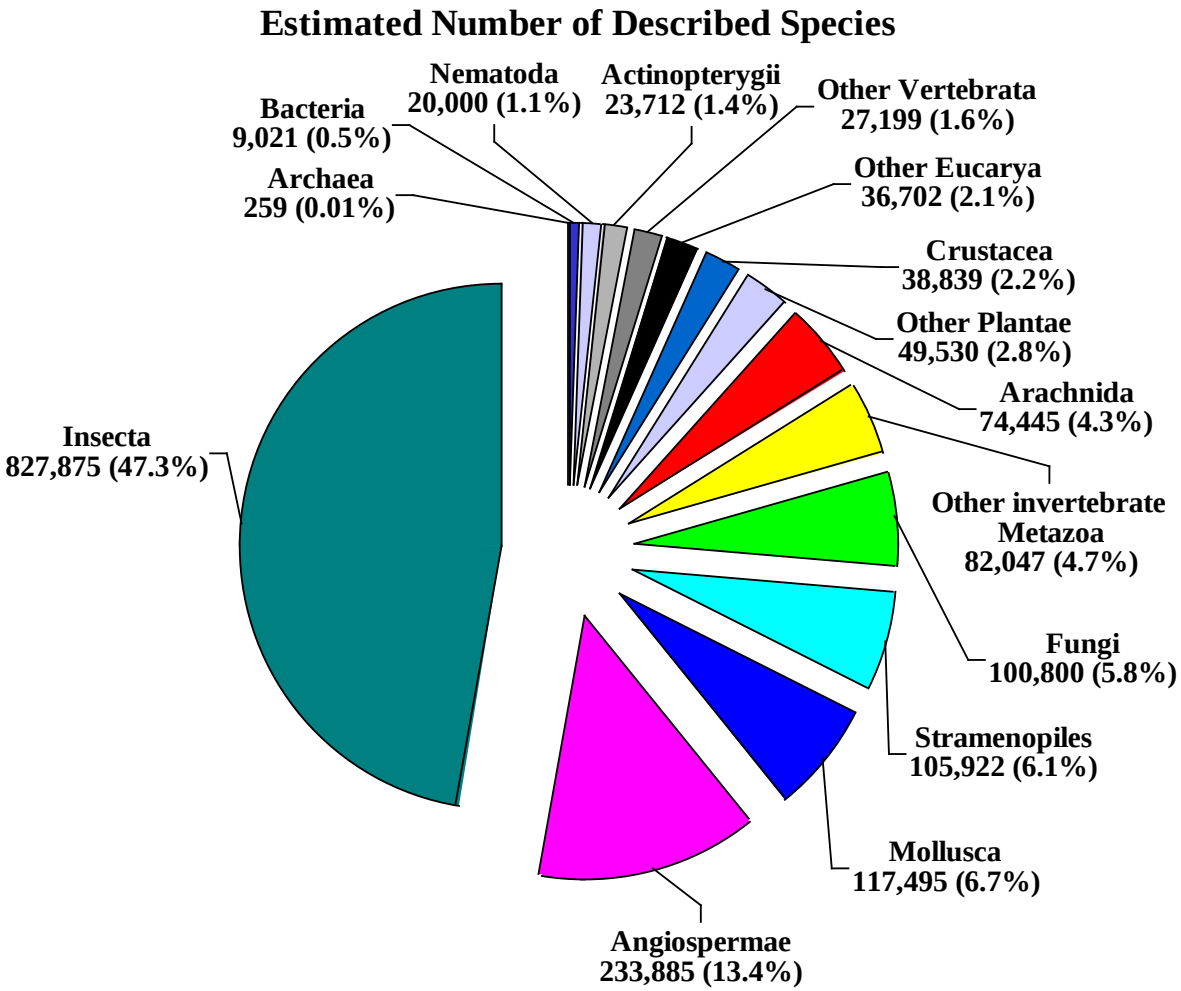
(Meffe *et al.* 2002)

Forest Conservation Biology

- Global Species diversity
  - How many species exist globally?
    - So far, ~1.5-1.75 million species have been identified
    - Scientists estimate that there are 3 to 100 million species on Earth
      - Current estimate of 8.7 million species (Mora et al. 2011)
        - » 2.2 million marine and the rest terrestrial
        - » Only includes eukaryotic organisms
        - » 86% of the species on Earth, and 91% in the ocean, have not been described

Forest Conservation Biology

- Global Species diversity



Forest Conservation Biology

- Hawai‘i Species diversity

Table 1. Numbers of presumed original colonists, derived native species, and endemic species for the major groups of Hawaiian biota.

	Minimum number of original colonists	Number of native species	Number of endemic species (% endemism)
Microscopic marine algae*	?	ca. 5000	?(probably low)
Macroscopic marine algae*†	?	ca. 500	54 (13%)
Ferns and fern allies 2‡§	ca. 114	145	102 (70%)
Mosses‖	225	233	112 (46%)
Gymnosperms	0	0	0
Flowering plants	ca. 260#	ca. 970**	ca. 880 (91%)
Marine decapods††	?	ca. 600	ca. 150–180
Terrestrial molluscs‡‡	22–24	ca. 1000	997 (99%)
Marine molluscs§§	?	ca. 1000	300–450 (30–45%)
Terrestrial arthropods‖ ‖	300–400	ca. 6000	ca. 5950 (99%)
Mammals	2	2	2 (100%)
Birds##	ca. 25	ca. 135	109 (81%)
Fish***†††	?	ca. 600	ca. 174 (29%)

Forest Conservation Biology

- Why is biodiversity important?
  - Intrinsic/inherent value
    - The value of something independent of its value to anyone or anything else
    - A philosophical concept
  - Extrinsic/utilitarian/instrumental value
    - Uses or applications of biodiversity

Forest Conservation Biology

- Values of Biodiversity

Land developer

Local communities

Oil company

Government agency

Source: Sterling/Frey © AMNH-CBC

Aquaculture company

Environmental group

Forest Conservation Biology

- Values of Biodiversity

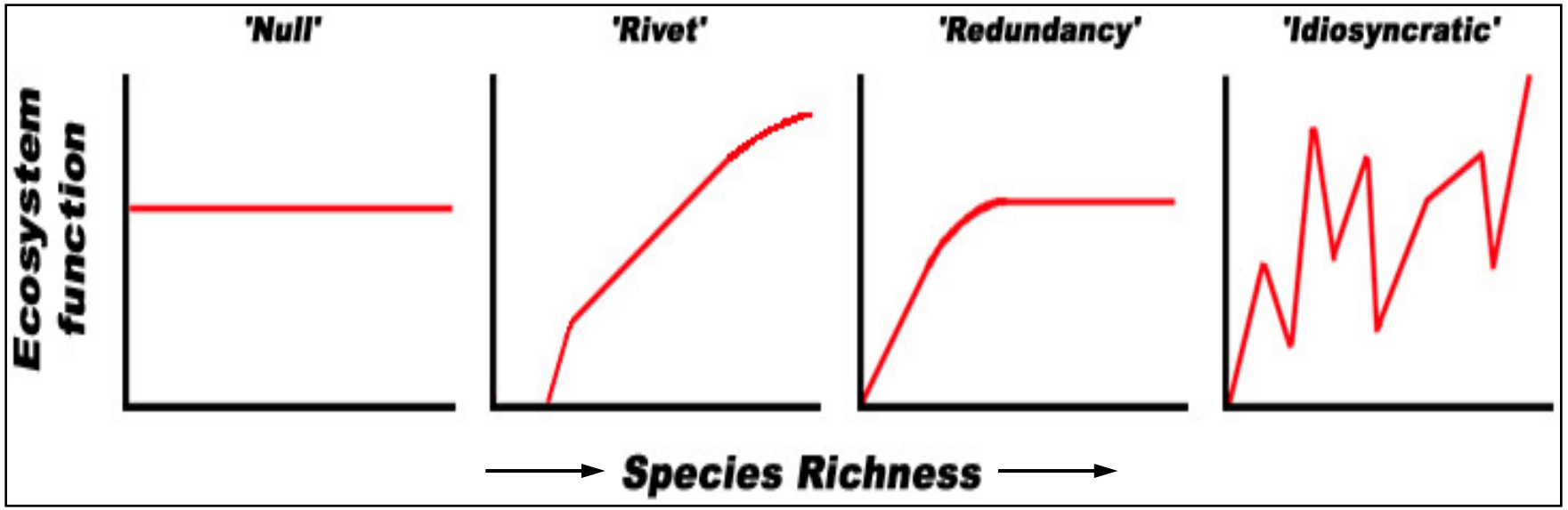
Direct Use Value(Goods)	***Indirect Use Value (Services)***	***Non-Use Values***	
Food, medicine, building material, fiber, fuel	**Atmospheric and climate regulation, pollination, nutrient recycling**	**Potential (or Option) Value**	**Future value either as a good or service**
	Cultural, Spiritual and Aesthetic	**Existence Value**	**Value of knowing something exists**
		Bequest Value	**Value of knowing that something will be there for future generations**

Forest Conservation Biology

- Biodiversity and Ecosystem Function
  - Is biodiversity important in determining the goods and services that ecosystems provide?
    - Stable ecosystems are characterized by (1 or more):
      - Constancy (Lack of fluctuation)
      - Resistance (Resistance to perturbation)
      - Resilience (Ability to recover)
    - Not all species are critical to ecosystem function
      - Many fill redundant roles
      - Basis for community stability (resistance and resilience)
    - If too many species (or a keystone species) are lost, it leads to the decline/failure of ecosystem function
      - Rivet-popper vs. Redundancy hypotheses

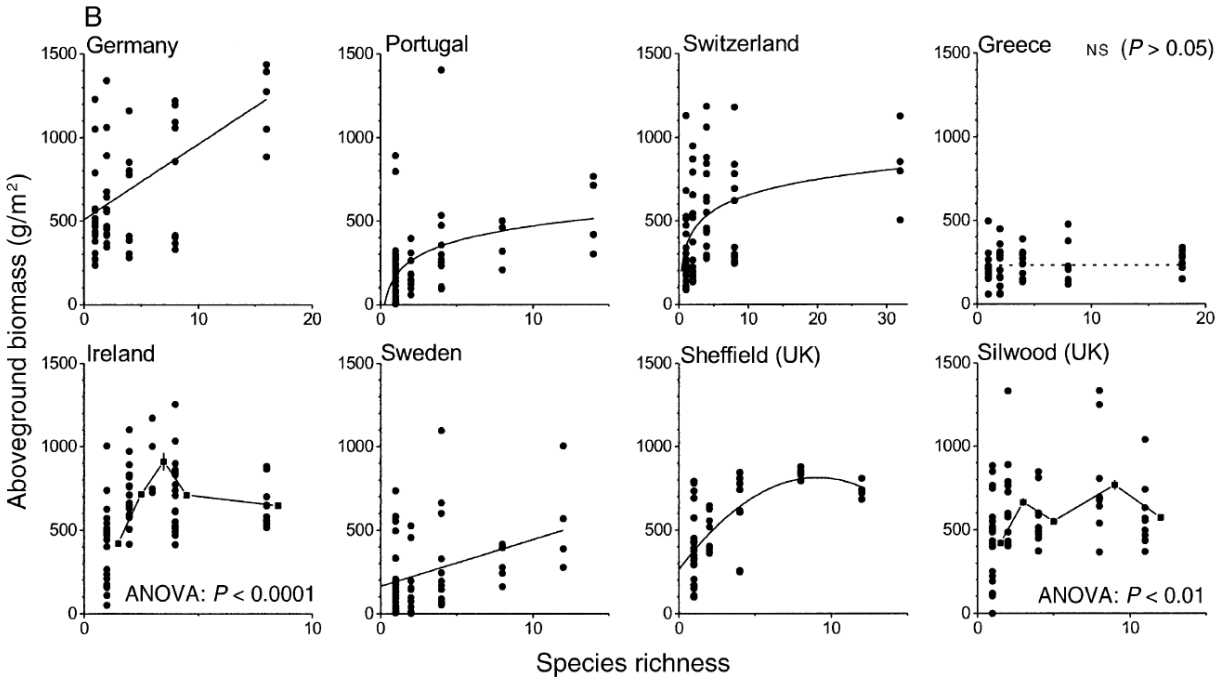
Forest Conservation Biology

- Biodiversity and Ecosystem Function
  - Is biodiversity important in determining the goods and services that ecosystems provide?



Forest Conservation Biology

- Biodiversity and Ecosystem Function
  - Studies indicate that there is a correlation between biodiversity & ecosystem function
    - Varies somewhat from system to system
      - Redundancy hypothesis has the most support



(Hooper et al. 2005)

Forest Conservation Biology

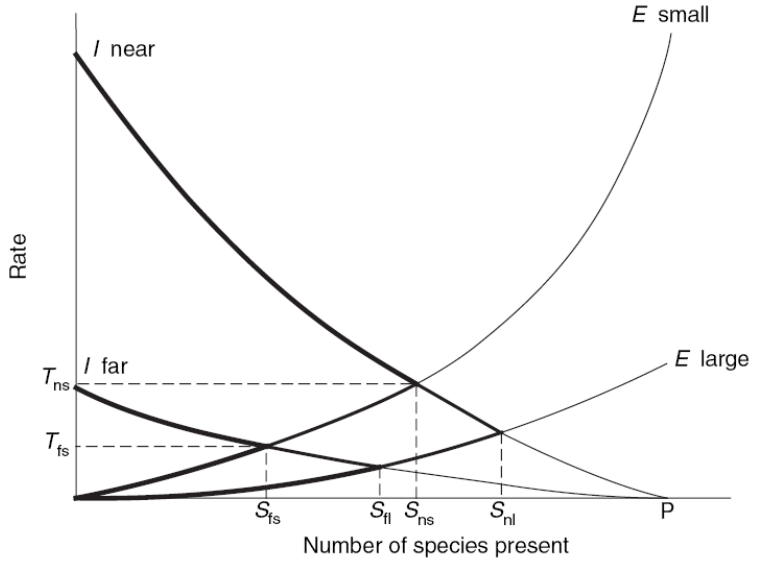
- What are the current threats to biodiversity?
  - Direct threats
    - Habitat loss and fragmentation
    - Invasive species
    - Overexploitation
    - Pollution
    - Global Climate Change

Forest Conservation Biology

- What are the current threats to biodiversity?
  - Underlying causes
    - Human population growth
    - Human over-consumption
      - Increased quality of life ≈ increased resource use
    - Lack of incentive for conservation
    - Lack of enforcement

Forest Conservation Biology

- Habitat loss and fragmentation
  - *The end result of human settlement and resource extraction in a landscape is a patchwork of small, isolated natural areas in a sea of developed land*… (Gascon et al. 1999)
    - Remnant patches are analogous to islands
    - Island Biogeography Theory
      - Biodiversity a function of island size & distance to other islands



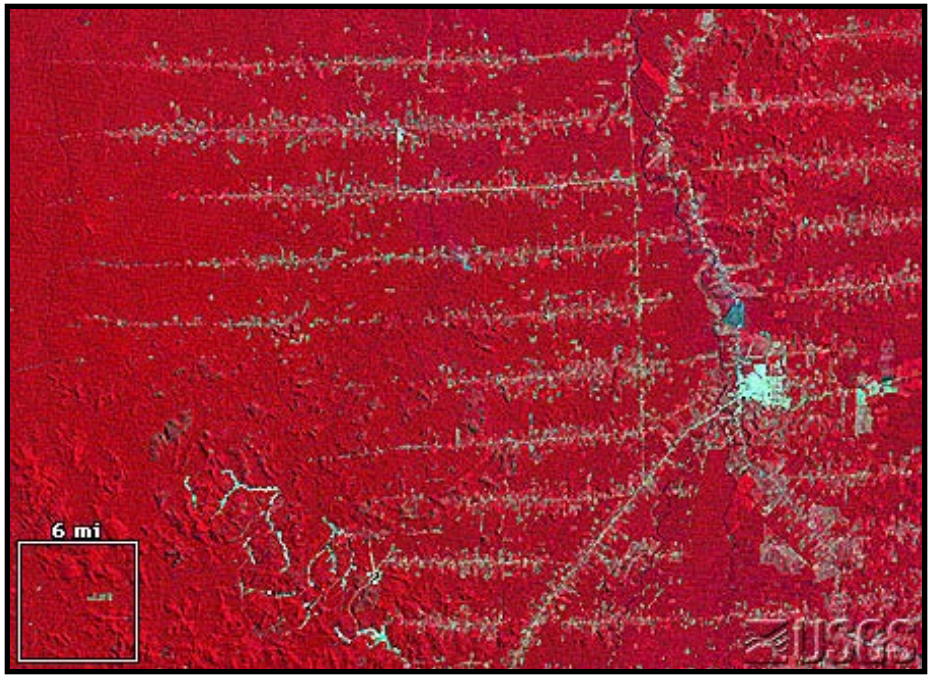
(MacArthur and Wilson 1967)

Forest Conservation Biology

- Habitat loss and fragmentation
  - Example from tropical moist forest in Rondonia, Brazil

1975

1986



Source:USGS EROS Data Center

Forest Conservation Biology

- Habitat loss and fragmentation

Patch Characteristic	***Natural***	***Human***
Structure	Complex	Simple
Wildlife habitat	Suitable to many species	Not always suitable & to fewer species
Contrast between patches	Lower	Higher
Edge effects	Less abrupt	Abrupt
Roads & other Human structures	Never	Uniquely occur and create unique dangers

Forest Conservation Biology

- Invasive Species

Hawaii

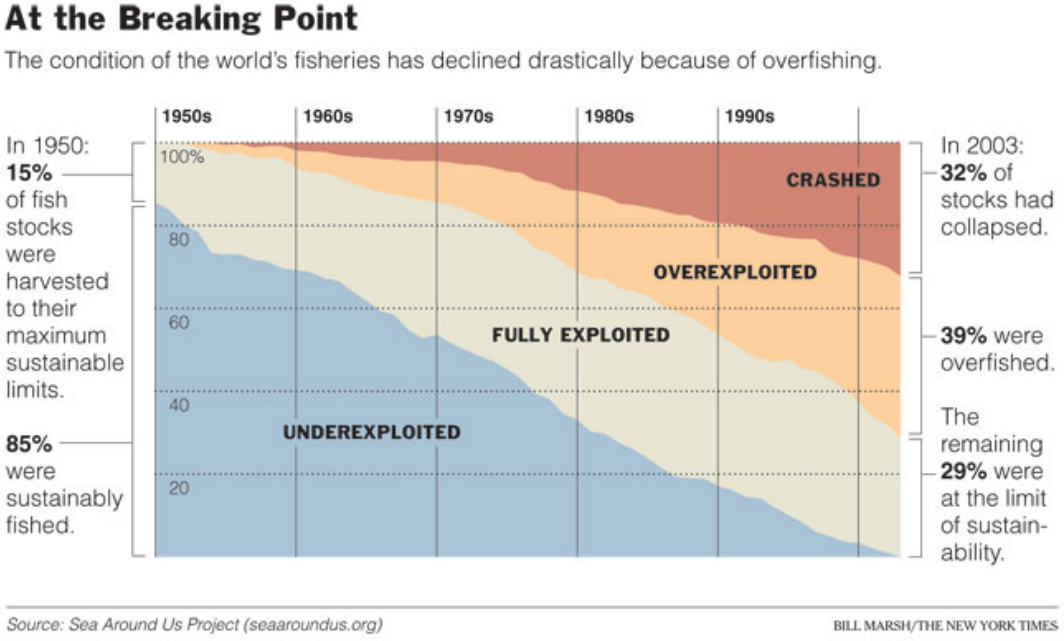
Psidium cattleianum

Pennisetum setaceum

***Puccinia* rust**

Forest Conservation Biology

- Overexploitation
  - Direct
    - Commercial harvests
  - Indirect
    - Unintentional harvests (e.g., bycatch)



Forest Conservation Biology

- Pollution

N fixation

← Natural →

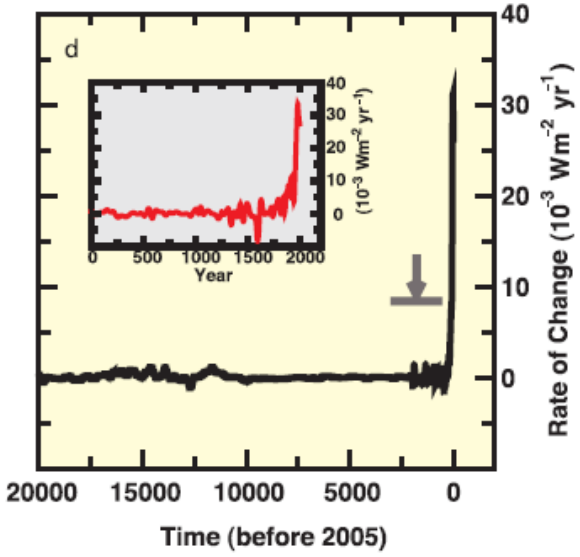
N deposition

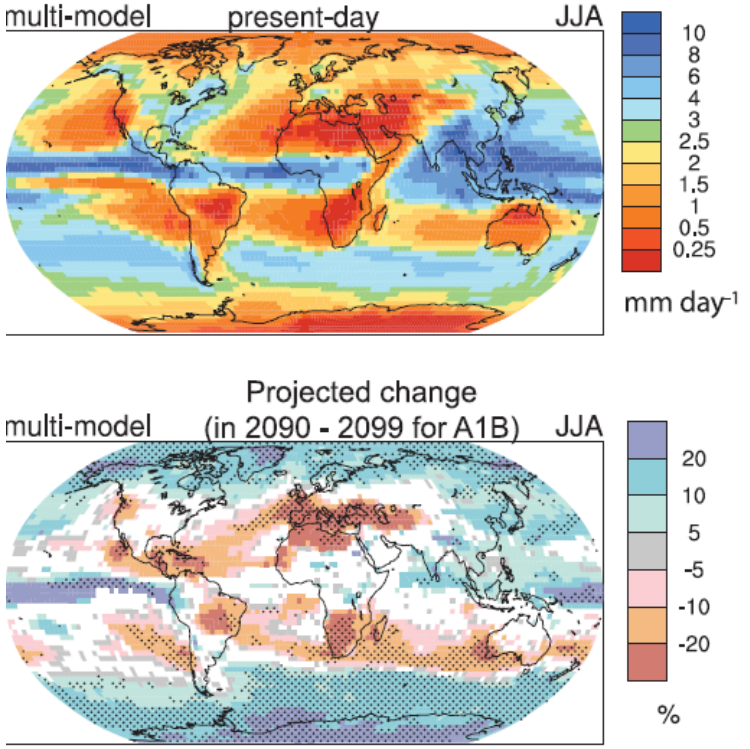
vs.

← Anthropogenic →

Forest Conservation Biology

- Global Climate Change





Forest Conservation Biology

- How do we manage forests to maximize biodiversity?
  - Restoration
  - Protection
  - Sustainable forest management
    - Includes sustainable harvest for financial income
  - Do not have to be mutually exclusive

Forest Conservation Biology

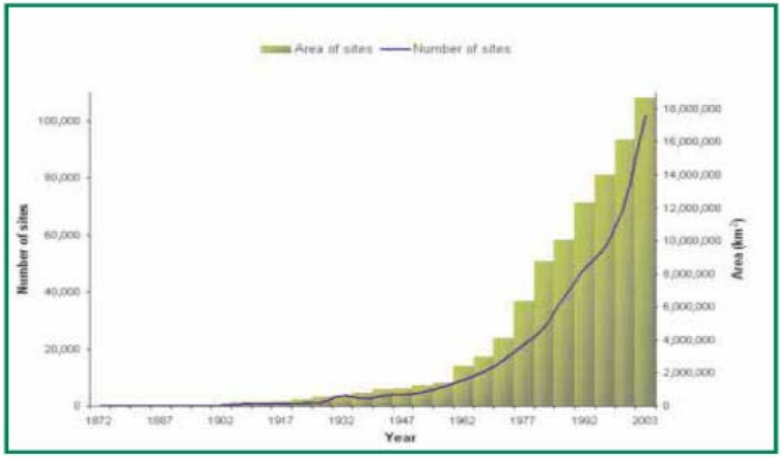
- Protection of biodiversity
  - What are protected areas?
    - *"An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means."* (IUCN)

Arctic National Wildlife Refuge/USFWS

Tropical beach © E. Naro-Maciel, AMNH-CBC

Forest Conservation Biology

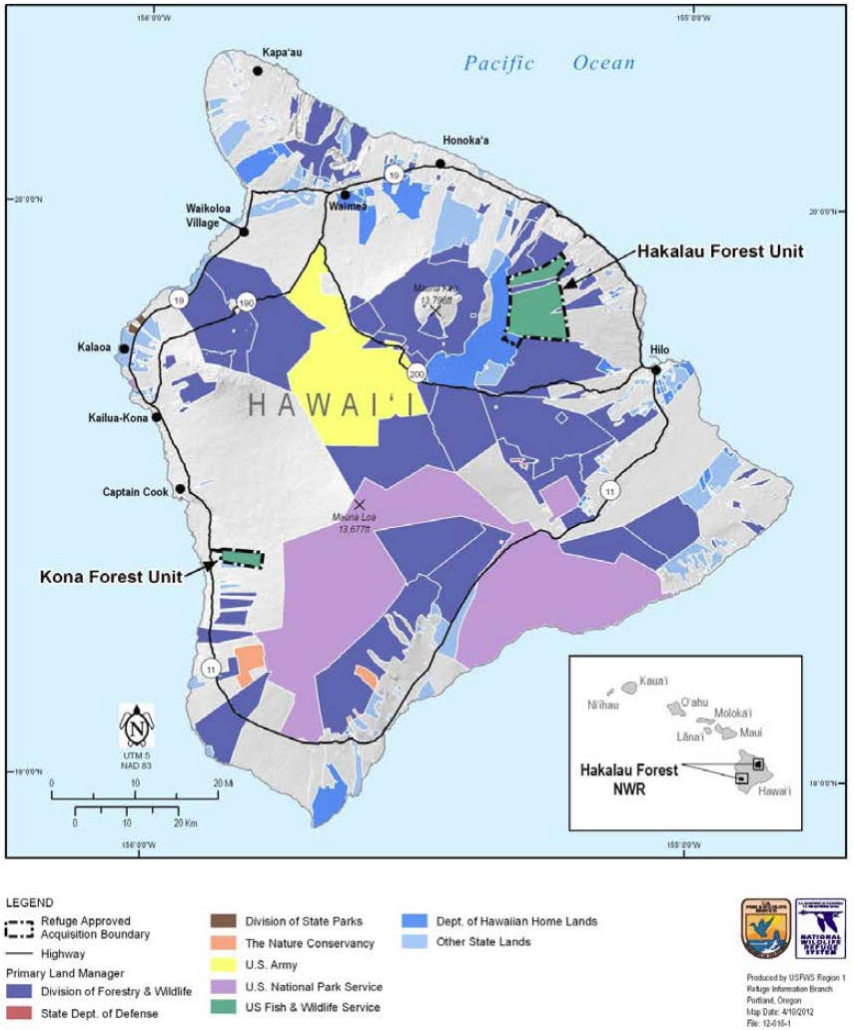
- Protection of biodiversity
  - Global protected areas
    - ~105,000 sites protecting ~12% of Earth's land surface
      - A large piece of this is Greenland, which contains the world's largest national park consisting primarily of snow
    - Most of these are terrestrial, and marine protected areas (MPAs) protect only ~0.5% of the world's oceans

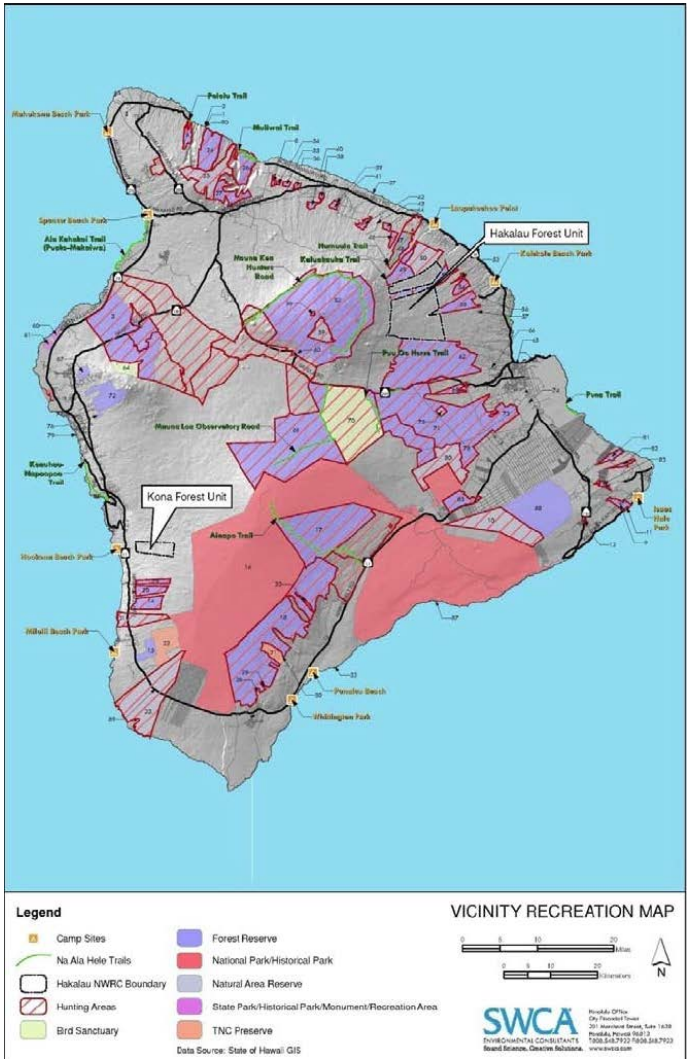


2003 UN List of Protected areas

Forest Conservation Biology

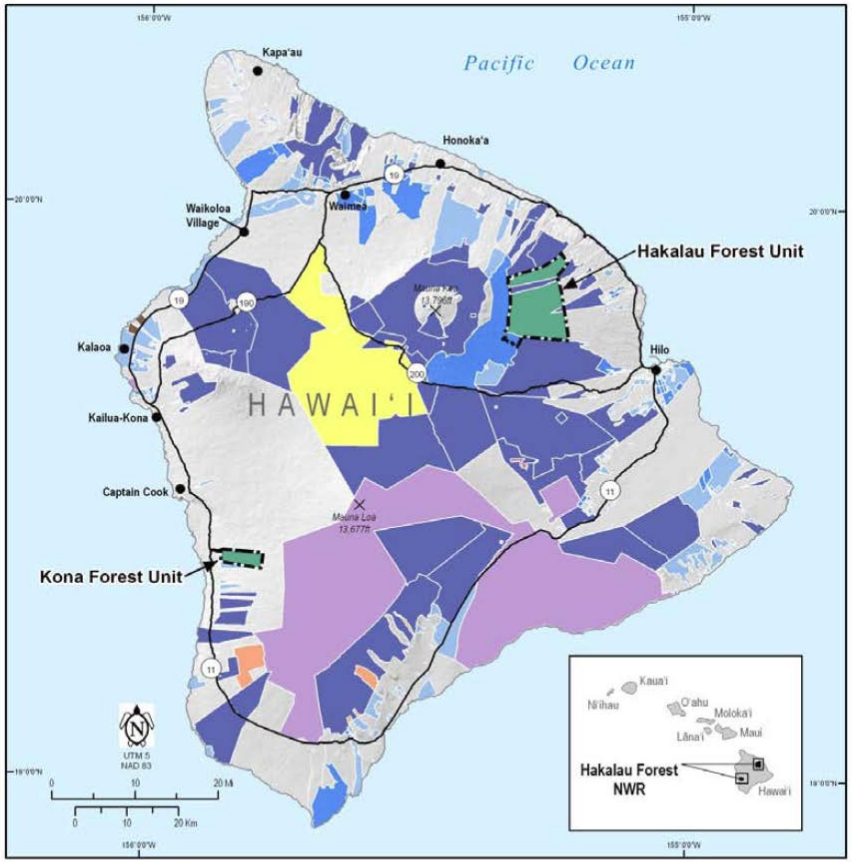
- Protection of biodiversity: Hawaii Forest Birds

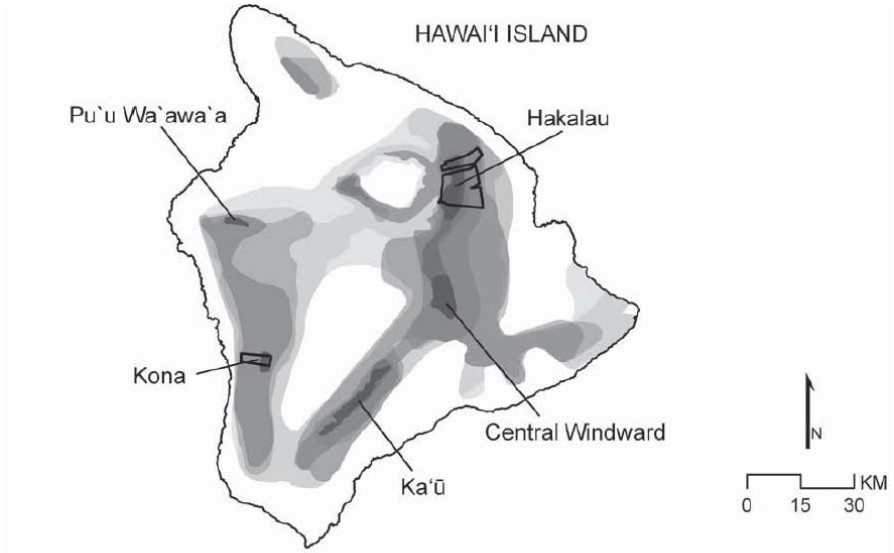




Forest Conservation Biology

- Protection of biodiversity: Hawaii Forest Birds





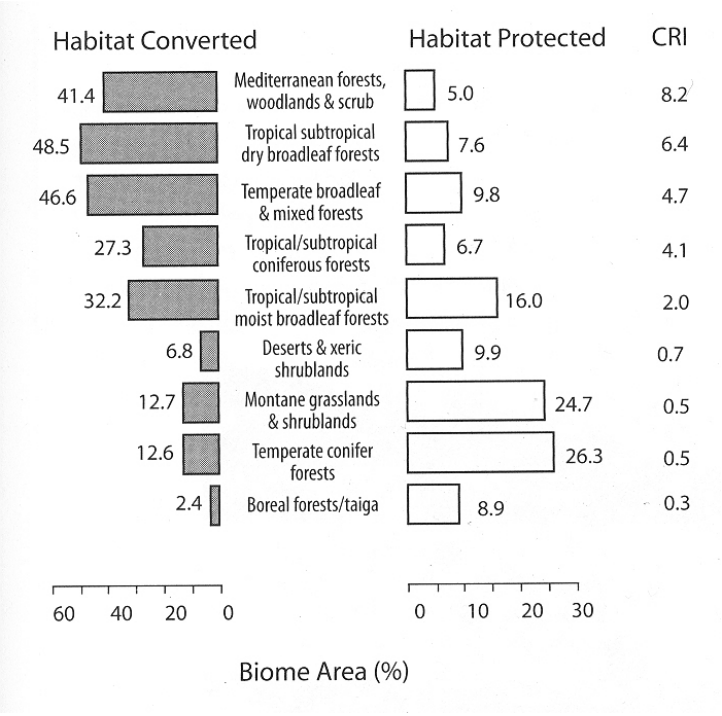
	Hakalau Forest NWR	Central Windward	Ka'ū	Kona Forest Unit HFNWR	Pu`u Wa`awa`a Wildlife Sanctuary
'Elepaio	▲	▼?	▼?	▼?	▼?
'Ōma'o	S or ▲	▼?	S	X	X
Hawai'i 'Amakihi	S	S	S	▲?	▲?
'Akiapōlā'au	▲	▼?	▼?	X	X
Hawai'i Creeper	▲	?	▼	X	▼
Hawai'i 'Ākepa	S or ▲	▼?	▼	▼	▼
'I'iwi	S	S	▼?	▼?	▼?
'Apapane	S	▲?	▲	▲	S?

Forest Conservation Biology

- Protection of biodiversity: Representativeness
  - Is existing protected area system representative?
    - **Most Protected Biomes**: Temperate conifer forests (25%), Flooded grasslands and savannas (18%) and tropical or subtropical moist broadleaf forests (18%)
    - **Least Protected Biomes**: Temperate grasslands, savannas, and shrublands (5%), Mediterranean forests, woodland and scrub (6%), and tropical or subtropical conifer forest (6%)

Forest Conservation Biology

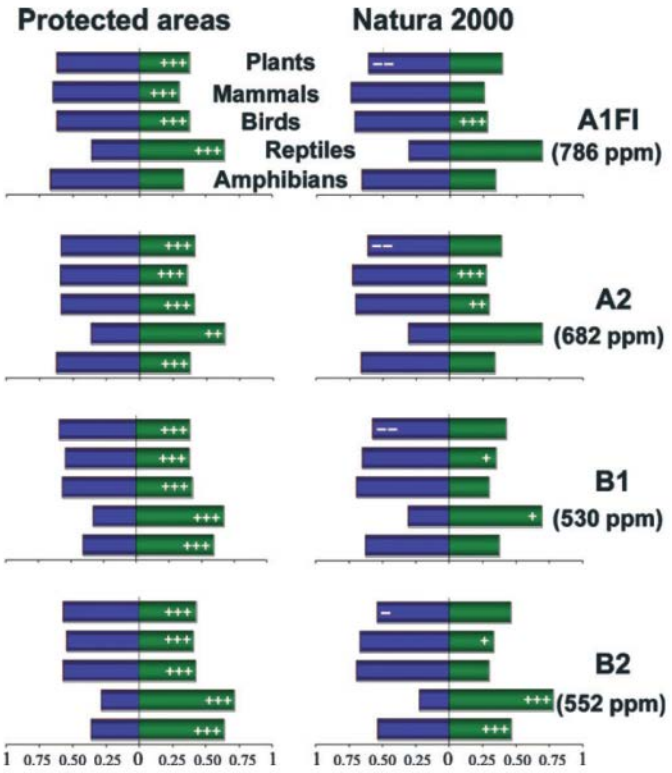
- Protection of biodiversity: Representativeness
  - Of the 11,633 species of mammals, amphibians, turtles, freshwater tortoises, & threatened birds analyzed, 12.2% (1424) of species are not covered by any protected area in the global network



(Perry et al., 2011)

Forest Conservation Biology

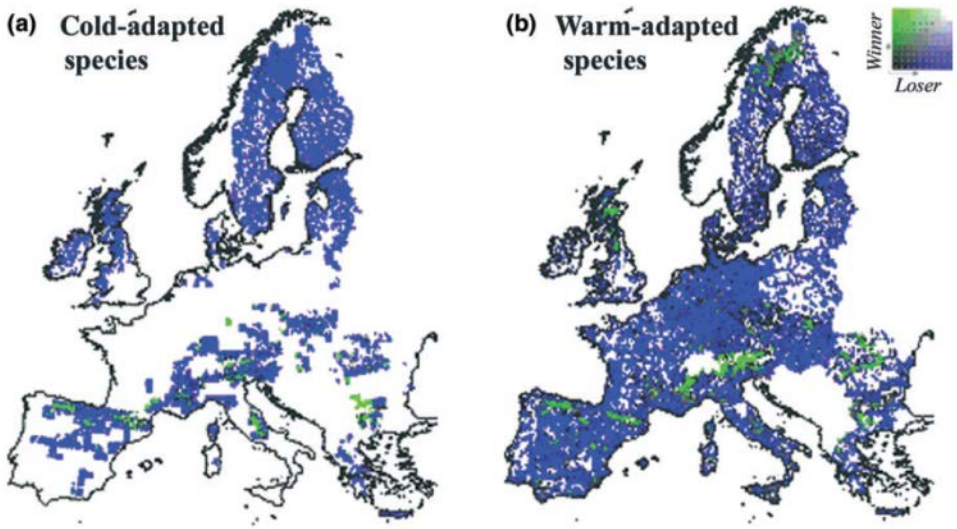
- Protection of biodiversity: Climate Change
  - How will current conservation areas conserve biological diversity with future climate change?

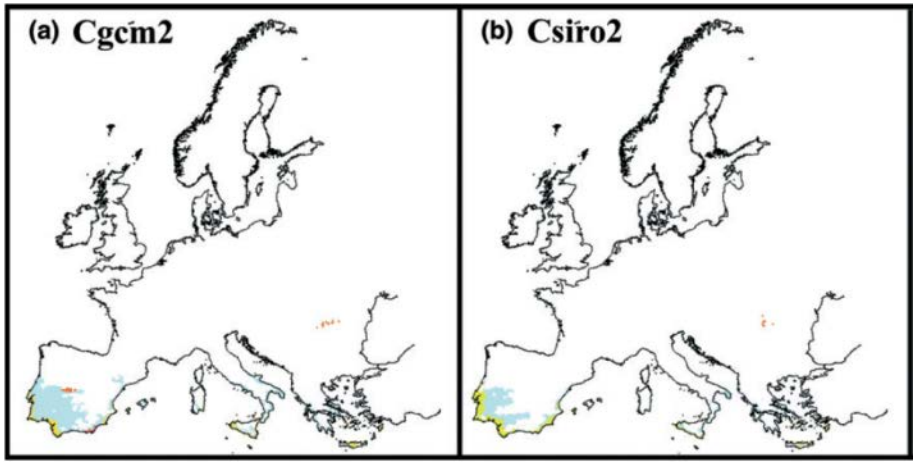


(Araújo et al., 2011)

Forest Conservation Biology

- Protection of biodiversity: Climate Change

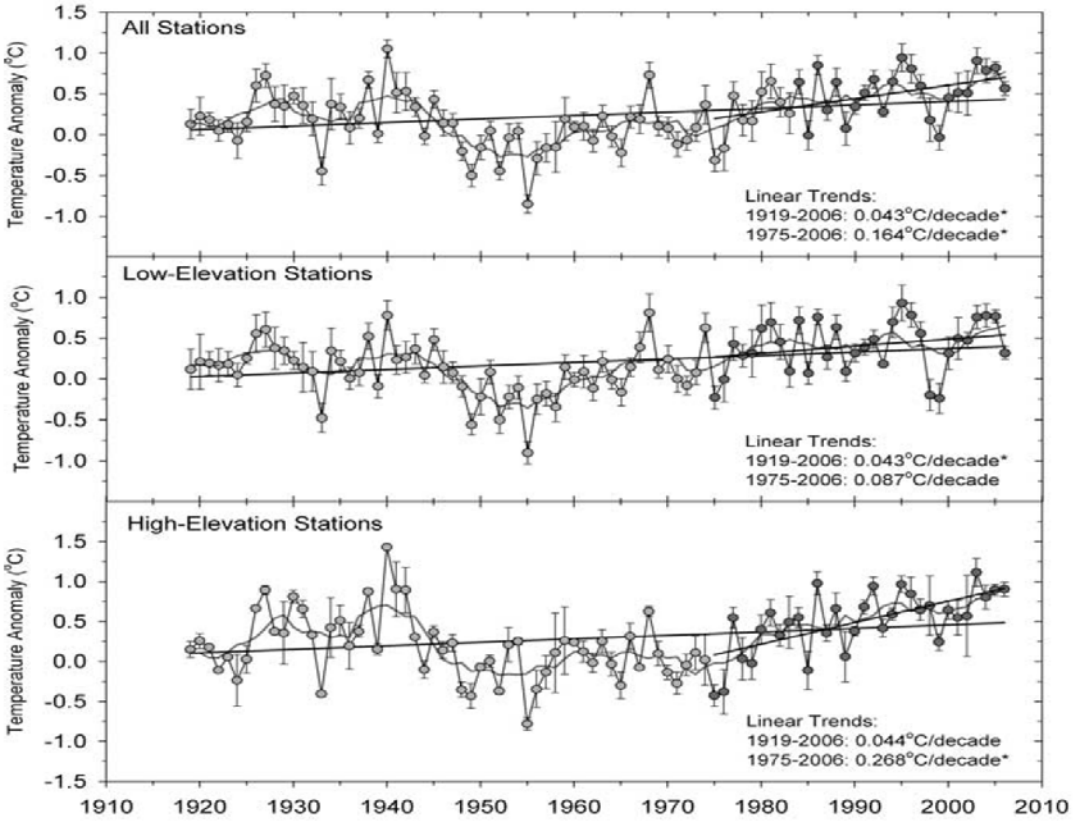




(Araújo et al., 2011)

Forest Conservation Biology

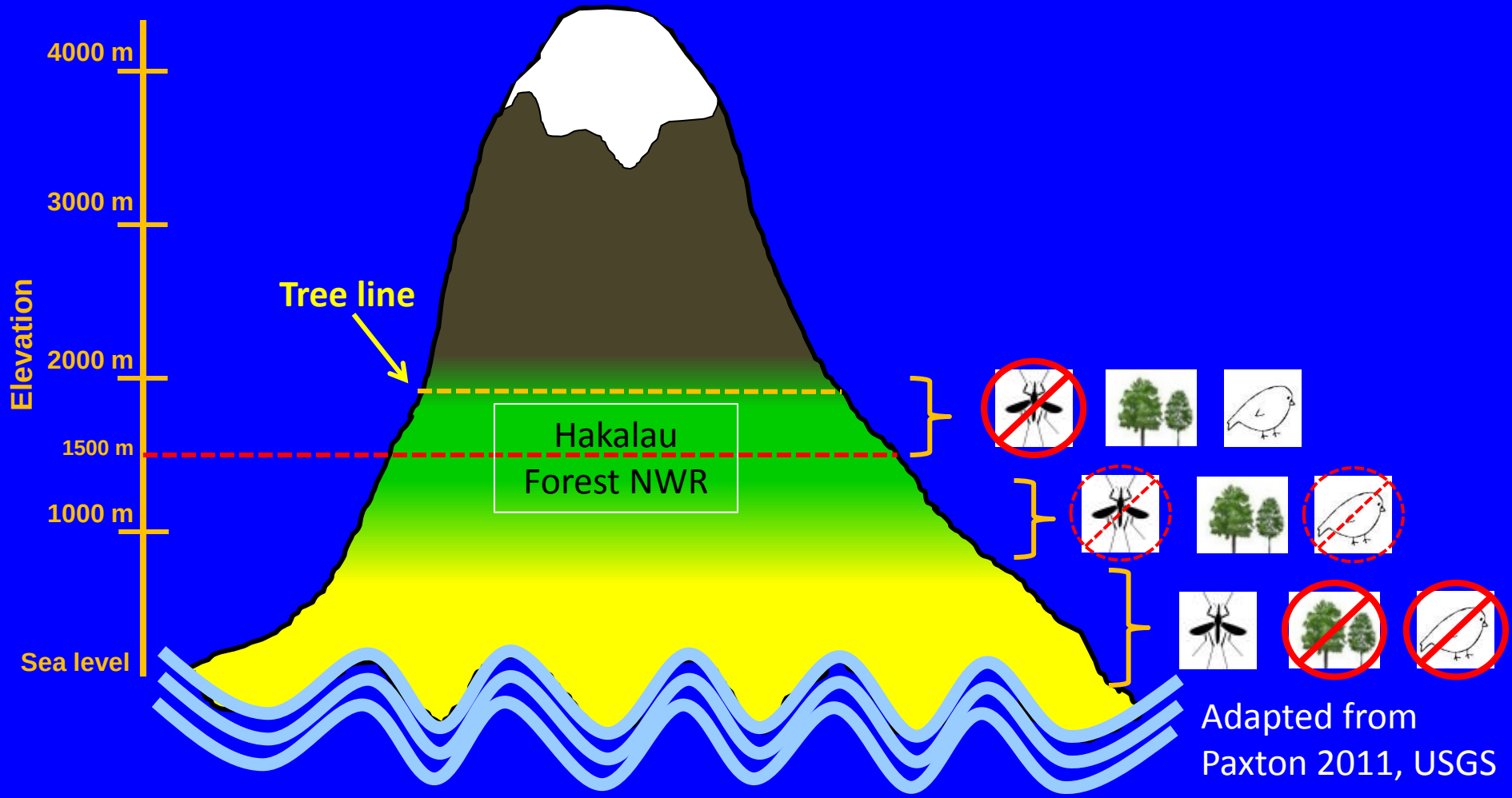
- Protection of biodiversity: Climate Change
  - –Hawaii will be removed from the impacts of climate change as a small oceanic island…?



(Giambelluca et al., 2008)

Causes for decline and extinction:

1) Habitat loss
2) Disease
   - Restricts most native birds to high elevation forest (~5,000 feet)



Adapted from Paxton 2011, USGS

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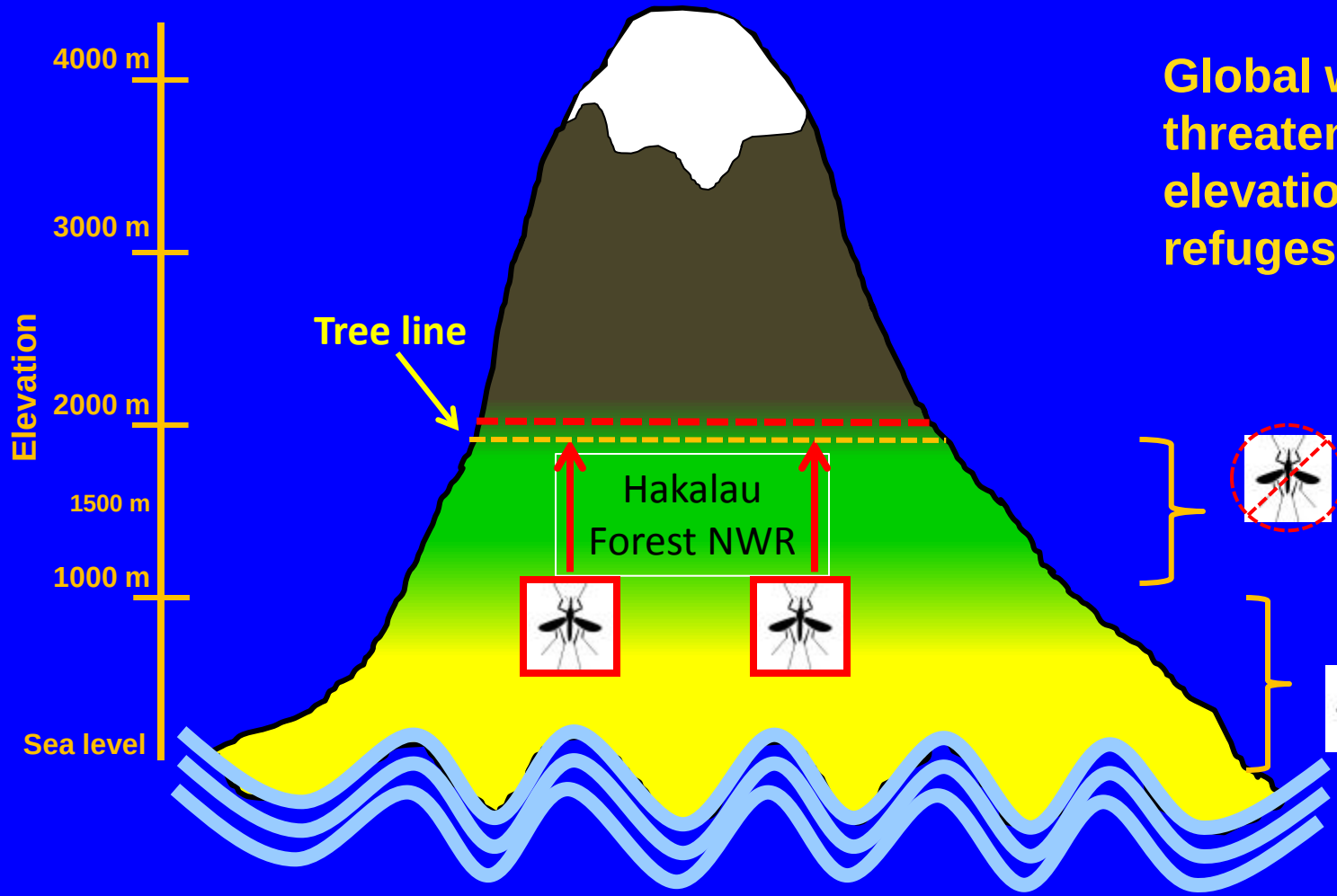
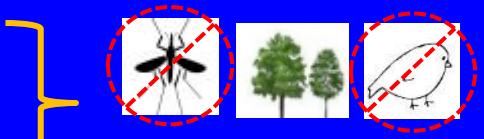


Global warming threatens high elevation forest refuges



Adapted from Paxton 2011, USGS

Forest Conservation Biology

- Making conservation “pay”
  - Integrated Conservation & Development Projects
    - Integrate biodiversity conservation & human livelihoods
  - Indigenous & Extractive Reserves
    - Lands allocated for use & habitation by native people
  - Conservation Concessions
    - Voluntary agreement where compensation is given for foregoing development on public or private lands
  - Debt for Nature swaps
    - Rich country NGO “buys” poor country’s debt with funds used for conservation activities managed by NGO
  - Ecotourism, agroforestry, PES, REDD+, etc.

Forest Conservation Biology

- Sustainable forest management (SFM)
  - "contribute to the management, conservation, & sustainable development of forests"
    - Relatively new concept (~1992), even though sustainable management is at least 200 years old
    - Environmental, social, and economic components of sustainability considered simultaneously
    - ~Reduced Impact Logging (RIL)
      - Well-trained workforce & careful harvest planning
      - Removal of climbers and lianas before felling
      - Directional tree felling
      - Riparian buffer zones
      - Improved technologies to reduce soil degradation

Forest Conservation Biology

- Sustainable forest management (SFM)

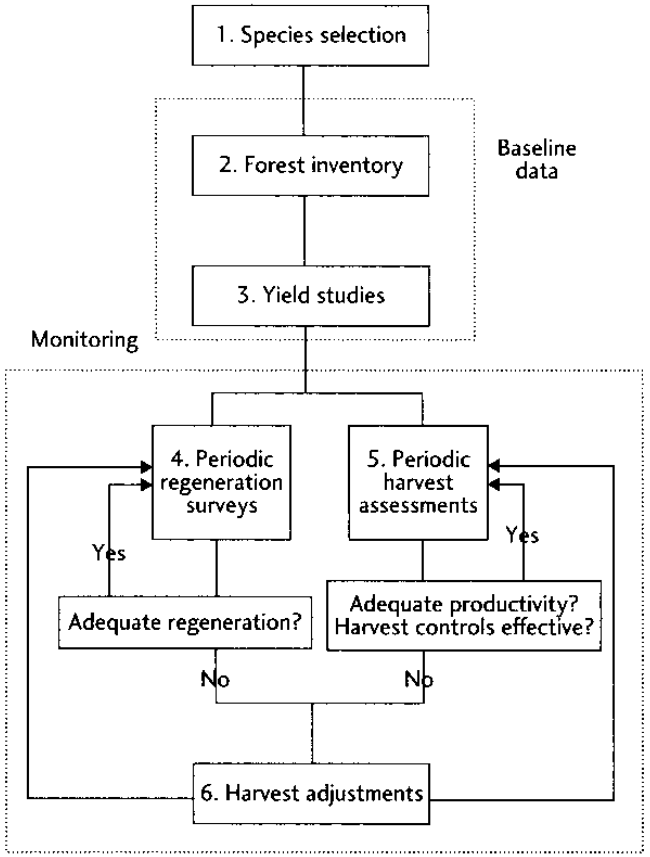


Table 8.2 The potential for sustainable use of different tree species, based on their biological characteristics (adapted from Peters 1994, http://www.panda.org.).

		Low	Moderate	High
Reproductive characteristics	Flower number, size	Few, large	Intermediate	Many, small
	Fruit number, size	Few, large	Intermediate	Many, small
	Reproductive phenology	Irregular, supra-annual	Regular, supra-annual	Regular, annual
	Pollination system	Biotic, with specialized	Biotic, with generalist	Abiotic
	Pollinator abundance	Low (bats, hummingbirds)	Moderate (beetles, moths)	High (small insects)
	Sprouting ability	None	Low	High
Regeneration processes	Seed dispersal	Biotic, with specialized vector	Biotic, with generalist vector	Abiotic
	Disperser abundance	Low (large birds, primates)	Moderate (small mammals)	High (small birds)
	Seed germination	Low viability; recalcitrant	Intermediate	High viability; orthodox
	Shade tolerance	Pioneer	Intermediate	Shade tolerant
	Regeneration niche	Narrow; specialized	Intermediate	Broad; generalist
*Population structure**	Size-class distribution	Type III curve (low representation in more than one size class)	Type II curve (low representation of reproductive adults)	Type I curve (inverse-J; exponential decay)
	Tree density	Low (0–5 adults ha^{-1})	Moderate (5–10 adults ha^{-1})	High (>10 adults ha^{-1})
	Spatial distribution	Scattered	Clumped	Evenly distributed

* See section 4.74.

Forest Conservation Biology

- Sustainable forest management (SFM)
  - Little evidence that SFM is effective
    - Biological
      - Indicators of forest biodiversity are insufficient
      - Inadequate accounting for ecosystem dynamics
    - Socioeconomic
      - Unrealistic goals, & lack of realistic incentives for locals
      - Projects generally not tied to market realities
      - High initial costs & need for well-trained workforce
      - Insufficient awareness of benefits
      - Lack of political incentives
      - Lucrative illegal timber market

Forest Conservation Biology

- Sustainable forest management (SFM)
  - Forest Certification via ‘labeling’
    - Promote a market for products to encourage SFM
      - Allows discerning customers to pay a premium price
      - Overcomes the economic drawbacks of SFM
    - Forest Stewardship Council (FSC)
      - Independent, non-governmental, non-profit organization
      - Sets standards for good management, & provides formal recognition for those meeting standards
    - Promising, but growth has been slow & of limited use
      - Environmentally aware market not large enough
      - Not really suitable for smallholder & community-based forests
        - » 25% of forest base & growing