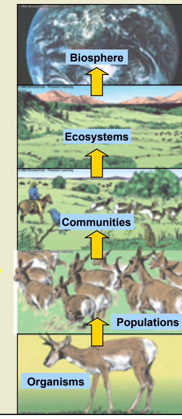
THE REALM OF ECOLOGY

- Biosphere
- Ecosystem
- Community
- **Population Ecology:** Interactions among members of the same species in a given habitat.



SPECIES and POPULATION

- Species
  - Interbreed
  - Fertile offspring
- Population
  - Interacting group
  - Share resources
  - Geographical range

POPULATION DYNAMICS

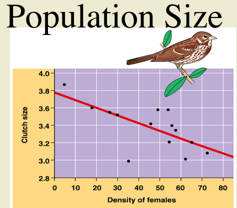
1. Size (N): # of individuals
2. Density: # of individuals per unit area
3. Distribution: dispersal within an area
4. Age structure: proportion in each age category
   - Often gender-specific
5. Growth patterns: changes in population size and/or density over time
6. Life history strategies: cost/benefit in stable vs. unstable environments

Factors that Limit Population Size

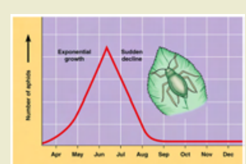
- **Abiotic (nonliving) Limiting Factors**
  - Temperature
  - Water
  - Soil type
  - Sunlight
  - Salinity
  - Wind stress
  - Altitude, depth
- **Biotic (living) Limiting Factors**
  - Food source
  - Competition
  - Predators
  - Social factors, mates
  - Pathogens, parasites
  - Vegetation

Factors that Limit Population Size

- **Density Dependent Limiting Factors**
  - Limited resources
    - Food
    - Water
    - Safe refuge
    - Predation
    - Competition
    - Living space
  - Disease, Pollution



- **Density Independent Limiting Factors**
  - Natural disasters
    - Hurricanes
    - Floods, landslides, volcanoes
    - Drought, frost
  - Environmental insult
    - Deforestation
    - Pesticide
    - Fire
  - Climatic change



Density, Dispersal, & Distribution

(a) Clumped. For many animals, such as these wolves, living in groups increases the effectiveness of hunting, spreads the work of protecting and caring for young, and helps exclude other individuals from their territory.

(b) Uniform. Birds nesting on small islands, such as these king penguins on South Georgia Island in the South Atlantic Ocean, often exhibit uniform spacing, maintained by aggressive interactions between neighbors.

(c) Random. Dandelions grow from windblown seeds that land at random and later germinate.

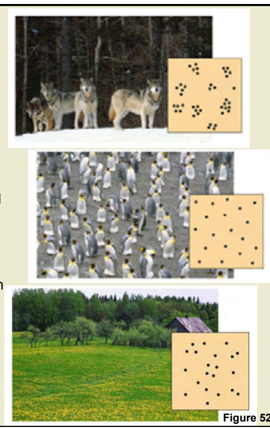


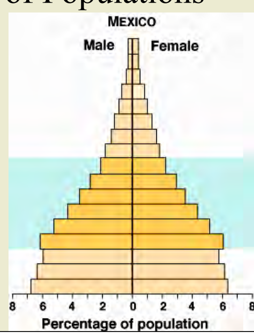
Figure 52.3

POPULATION AGE STRUCTURE

- Demography & Life Tables
- Survivorship Curves

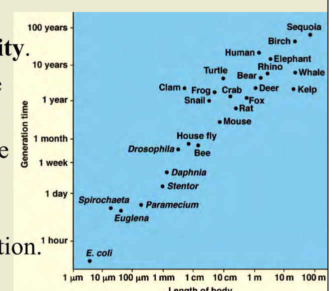
POPULATION AGE STRUCTURE
Vital Statistics of Populations

- **Age structure** is relative number of individuals of each age. **Sex ratio** is % of females to males.
- Study of human populations = **demography**



POPULATION AGE STRUCTURE
Vital Statistics of Populations

- Average births per individual = **fecundity**.
- Population birth rate = **natality.**
- Population death rate = **mortality.**
- **Generation time** = age at first reproduction.



Life Tables

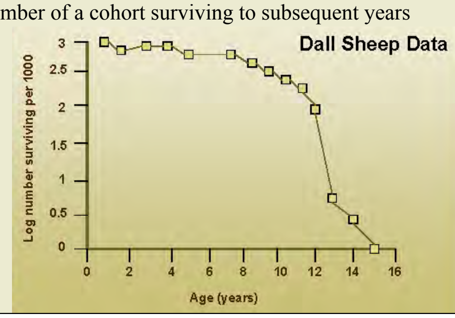
- Created in one of two ways:
  1. Follow a **cohort**. or
  2. Snapshot of a population at a specific time point.

Life Table for Great Tits *(Parus major)* in Scotland — TABLE 47.1

	AGE	NUMBER ALIVE AT BEGINNING OF YEAR	PROPORTION OF COHORT SURVIVING TO BEGINNING OF YEAR	NUMBER OF DEATHS DURING YEAR	PORPORTION OF COHORT DYING DURING YEAR	NUMBER OF SUCCESSFUL FLEDGLINGS PER INDIVIDUAL
Female	1	1000	1.000	613	0.613	0.359
	2	387	0.387	216	0.558	0.370
	3	171	0.171	95	0.556	0.401
	4	76	0.076	39	0.513	0.518
	5	37	0.037	23	0.622	0.328
	6	14	0.014	10	0.714	0.154
	7	4	0.004	3	0.750	0.000
	8	1	0.001	—	—	0.000
Male	1	1000	1.000	575	0.575	0.326
	2	425	0.425	212	0.499	0.392
	3	213	0.213	104	0.488	0.425
	4	109	0.109	65	0.596	0.580
	5	44	0.044	21	0.477	0.293
	6	23	0.023	15	0.652	0.383
	7	8	0.008	6	0.750	0.643
	8	2	0.002	—	—	0.000

POPULATION AGE STRUCTURE
Cohort Survivorship Curve

- Number of a cohort surviving to subsequent years



POPULATION AGE STRUCTURE
Cohort Survivorship Curve

- Number of a cohort surviving to subsequent years

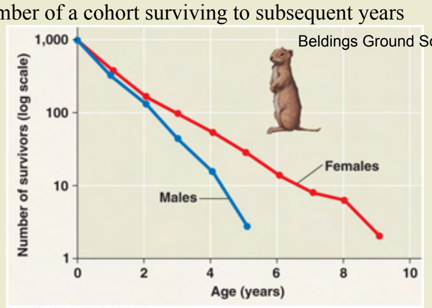
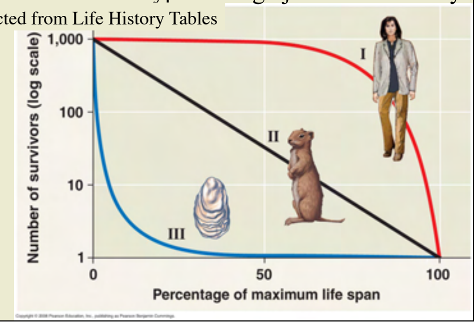


Fig. 53.5

Survivorship Curves

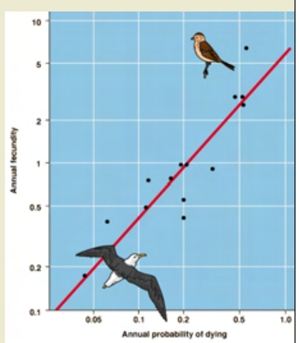
- Type I: low juvenile mortality
- Type II: constant mortality
- Type III: high juvenile mortality

- Constructed from Life History Tables



Fecundity Influences Mortality

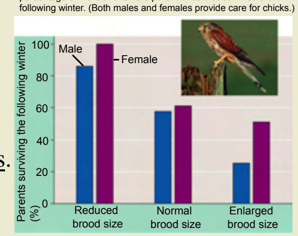
- Survivorship curves reflect life tables.
- Tradeoffs exist between survivorship & reproductive traits.
- There is a balancing allocation of resources.



Fecundity Influences Mortality

- Survivorship curves reflect life tables.
- Tradeoffs exist between survivorship & reproductive traits.
- There is a balancing allocation of resources.

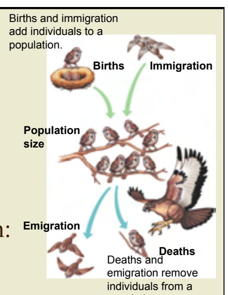
EXPERIMENT Researchers in the Netherlands studied the effects of parental caregiving in European kestrels over 5 years. The researchers transferred chicks among nests to produce reduced broods (three or four chicks), normal broods (five or six), and enlarged broods (seven or eight). They then measured the percentage of male and female parent birds that survived the following winter. (Both males and females provide care for chicks.)



CONCLUSION The lower survival rates of kestrels with larger broods indicate that caring for more offspring negatively affects survival of the parents.

Figure 52.7

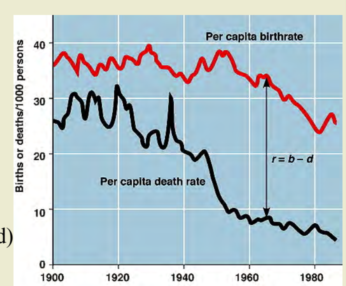
Population growth patterns: changes over time



- Population size (N) depends on:
  - Natality = birth rate (b)
  - Mortality = death rate (d)
  - Immigration = migration into the population (i)
  - Emigration = migration out of the population (e)
  - Growth rate (r) = (b-d) + (i-e)

Population Growth Rate

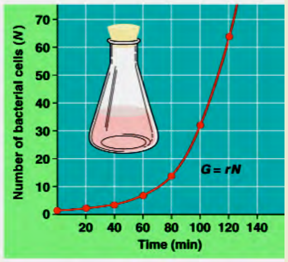
- N = # individuals
- ΔN/Δt = change in population size over time
- ♦ b = birth rate
- ♦ d = death rate
- ΔN/Δt = (N*b)–(N*d)
- *r* = b–d
- ΔN/Δt = ***r*N**



- In Sri Lanka, overpopulation continues to escalate despite success in decreasing per capita birth rate.
- ↓↓d→↑r, despite ↓b. ↑r →↑ ΔN/Δt

Exponential Growth

Time	Number of Cells	
0 minutes	1	$= 2^0$
20	2	$= 2^1$
40	4	$= 2^2$
60	8	$= 2^3$
80	16	$= 2^4$
100	32	$= 2^5$
120 (= 2 hours)	64	$= 2^6$
3 hours	512	$= 2^9$
4 hours	4096	$= 2^{12}$
8 hours	16,777,216	$= 2^{24}$
12 hours	68,719,476,736	$= 2^{36}$

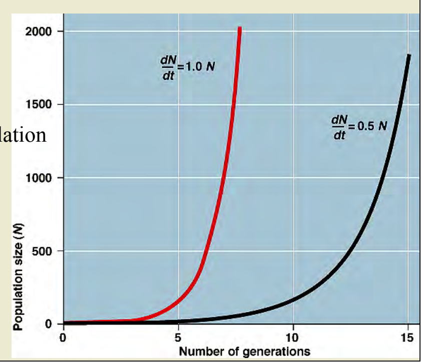


- Population multiplies by a constant factor.
- Growth rate not limited by resources.
- **<u>"J"-shaped</u>** growth curve.

- r : population growth rate
- r_{max} : **biotic potential**
  - potential growth rate under ideal conditions
- K : **carrying capacity**
  - maximum population that the environment can sustain over long periods of time.
  - determined by biotic and abiotic **limiting factors**.

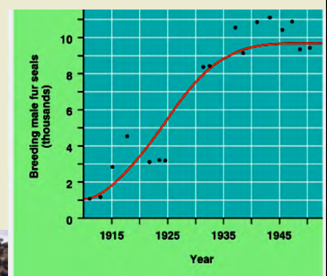
Exponential Growth Curves

- Growth = $\Delta N/\Delta t = \boldsymbol{r}\mathbf{N}$
  - $\{r = b - d\}$
- Rate of population growth only limited by r_{max}.
- "r-limited"



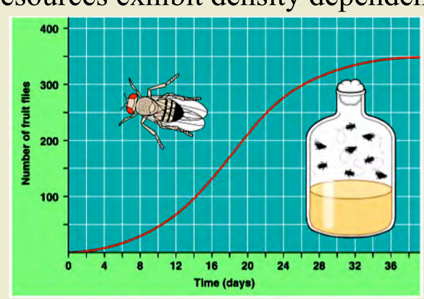
Logistic growth

- Growth is limited by density-dependent resources or other factors
- Decrease growth rate produces **<u>"S"-shaped</u>** (sigmoidal) curve
- "K-limited"



Fur seal population

Laboratory populations with defined resources exhibit density dependence



"K-selected"

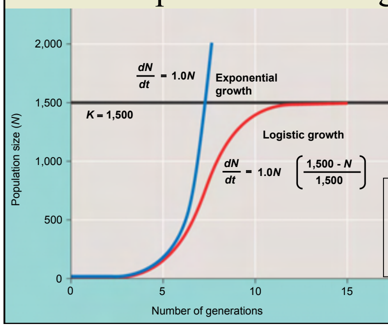
Growth Equations: Exponential vs. Logistic

- Exponential
  - **Growth rate (G) = dN/dt = $\boldsymbol{r}$N**
  - This growth is always increasing.
- Logistic
  - **Growth rate (G) = dN/dt = $\boldsymbol{r}$N([K-N]/K)**

❑ When N <<< K (pop is v. low), [K-N] = K and **dN/dt** = rN(K/K) = **$\boldsymbol{r}$N** (growth is exponential).

❑ When N approaches K, [K-N] approaches zero and **dN/dt** = rN(0/K) = **0** (growth stops).

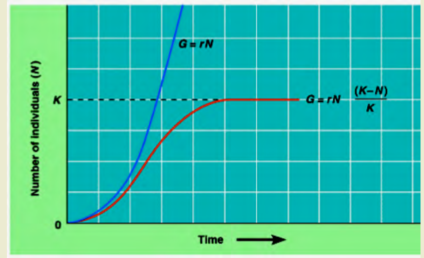
Growth Equations: Exponential vs. Logistic



- Exponential
  - dN/dt = *r*N
- Logistic
  - dN/dt = *r*N([K-N]/K)

Figure 52.12

A population reaches carrying capacity when growth rate is zero



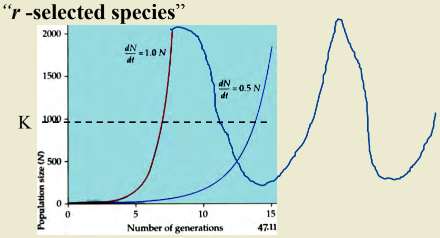
- **"r-selected": J-type growth rate limited by r, but cannot be sustained indefinitely beyond K.**
- **"K-selected": S-type growth rate limited by K**

Carrying Capacity

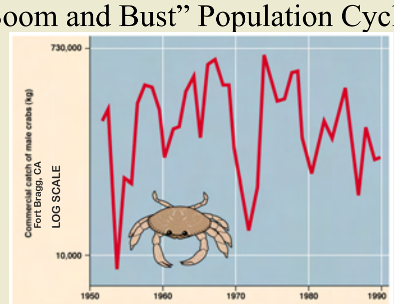
- Population size that can be **sustained** by a habitat
- Requires **renewable** resources
- Carrying capacity (K) changes as resources flux with size of population
- If a population does not limit its size to the carrying capacity, it will deplete its resources and suffer a sharp crash in numbers due to starvation and/or disease — "boom & bust" pattern.

Outcome of Exponential Growth

- Exceed carrying capacity (K) & crash.
  - cyclic exponential ("J-shaped) growth curves punctuated by crashes.
  - typical of species who make **tons** of tiny kids
  - "***r*** **-selected species**"

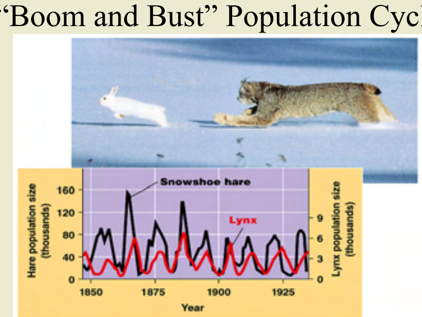


"Boom and Bust" Population Cycles



- **"r-selected"**
- Population cycles between a rapid increase and then a sharp decline.

"Boom and Bust" Population Cycles



- **"r-selected"**
- Population cycles between a rapid increase and then a sharp decline.

Trophic (food resources) limiting factors

- **Top-down regulation** (populations regulated by higher levels of the food chain)**:** increase in predator (lynx) population causes a decrease in the prey (hare) population.
  - Original hypothesis

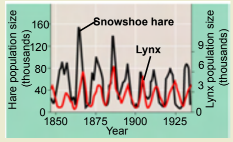


Figure 52.21

- **Bottom-up regulation** (populations regulated by lower levels of the food chain)**:** increase in hare population causes an over-consumption of the vegetation; decrease in vegetation causes a decrease in hare population; decrease in hare population causes a decrease in predator (lynx) population
  - Revised hypothesis. Hare populations oscillate even in the absence of lynxes.

Life History Traits

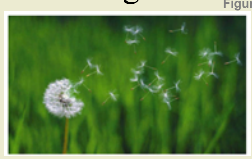
Trade-offs, **game theory** and the **allocation of resources**

- For species inhabiting unstable, unpredictable environments; or species with very high juvenile mortality:
  - The odds of suitable habitat for the next generation are low.
  - Therefore, natural selection favors the **generalist** populations that opportunistically harvest any available resource to grow as fast as possible when they can, and quickly produce many offspring distributed over a wide area to increase chance of hitting someplace good. ("weeds")
  - "**r-selected**" — select for high reproductive potential
- For species inhabiting stable environments:
  - Long-term strategy is most successful.
  - Natural selection favors the **specialist** populations that excel at harnessing the particular available resources to displace competitors. Spend resources on becoming dominant species and increasing the odds of a few offspring to succeed with you.
  - "**K-selected**" — select for intrinsic growth limitations for sustainable population over time.

Reproductive Strategies

Figure 52.8

- Semelparity
  - Produce one huge batch of offspring and then die

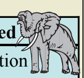


(a) Most weedy plants, such as this dandelion, grow quickly and produce a large number of seeds.

- Iteroparity
  - Produce several smaller batches of offspring distributed over time

(b) Some plants, such as this coconut palm, produce a moderate number of very large seeds.

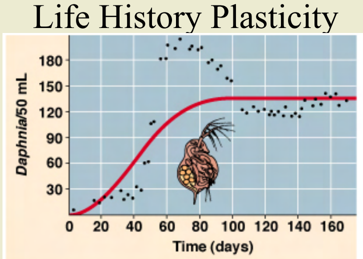
Life History Traits

Type:	**r-selected**	**K-selected**
Major source of mortality	Juvenile predation / Sporadic catastrophes	Competition
Generation time (age)	Short (young)	Long (old)
Adult size	Small	Large
Reproduction	Semelparous	Iteroparous
Fecundity	Very high	Low
Newborn size	Small	Large
Dispersal of young	High	Low
Parental care	Low/none	High
Newborn behavior	Precocial	Altricial
Juvenile mortality	Very high	Low
Survivorship curve	Type III	Type I
Pop. growth curve	Cyclic	Sigmoidal

Life History Plasticity

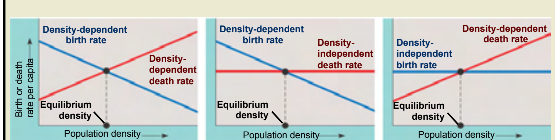
Daphnia ostracod in culture



- Switch from r-limited growth to K-limited, before environmental degradation is irreversible.
  - At low population densities, short generation time, high fecundity.
  - At high densities, change physiology to longer generation time, more body growth, lower fecundity.

K-selected populations

- Equilibrium population density (b=d) at or below carrying capacity.
- Must either ↑d or ↓b or both.



(a) Both birth rate and death rate change with population density.

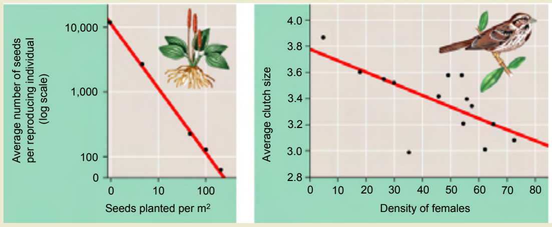
(b) Birth rate changes with population density while death rate is constant.

(c) Death rate changes with population density while birth rate is constant.

Figure 52.14

K-selected populations

- "Good" K-selected species achieve equilibrium density by decreasing birth rate as population approaches K.



(a) Plantain. The number of seeds produced by plantain (*Plantago major*) decreases as density increases.

(b) Song sparrow. Clutch size in the song sparrow on Mandarte Island, British Columbia, decreases as density increases and food is in short supply.

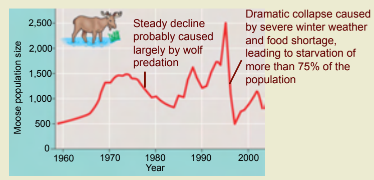
Figure 52.15

Even K-limited populations may fluctuate over time

- Variations in limiting factors cause variations in ***K***

FIELD STUDY Researchers regularly surveyed the population of moose on Isle Royale, Michigan, from 1960 to 2003. During that time, the lake never froze over, and so the moose population was isolated from the effects of immigration and emigration.

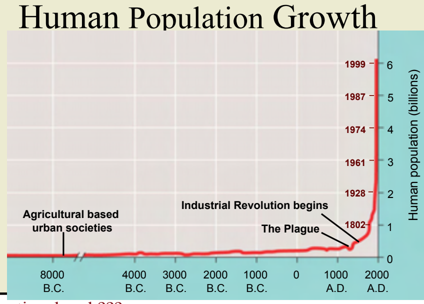
RESULTS Over 43 years, this population experienced two significant increases and collapses, as well as several less severe fluctuations in size.



CONCLUSION The pattern of population dynamics observed in this isolated population indicates that various biotic and abiotic factors can result in dramatic fluctuations over time in a moose population.

Figure 52.18

Human Population Growth



- Paradox or time bomb???
- *Homo sapiens* life history traits show Type I survivorship that should correlate with a K-selected sigmoidal growth curve.
- But, our actual growth curve is exponential!!!
- **What happens to a population that exceeds its carrying capacity?**

Humans can artificially increase carrying capacity

- Technological advances avoid natural growth constraints
  - Hunting and gathering
  - Agricultural revolution
  - Industrial revolution
  - Scientific revolution

Age structure pyramids

- Zero population growth = High birth rates – High death rates
- Zero population growth = Low birth rates – Low death rates

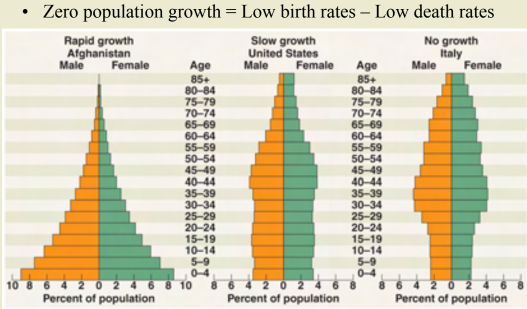
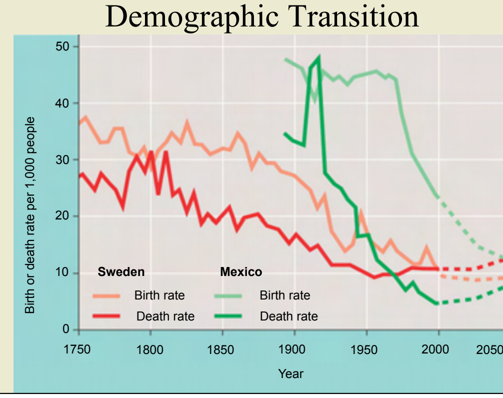


Fig. 53.25

Demographic Transition

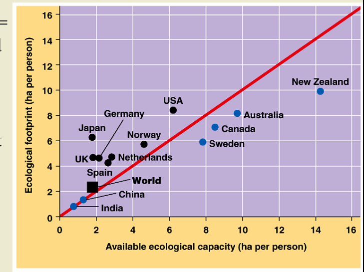


Human carrying capacity is not infinite

- Resources will eventually be depleted
- Economic resources allow exploitation of natural resources
- Industrialized nations consume more resources per capita

Earth's Human Carrying Capacity

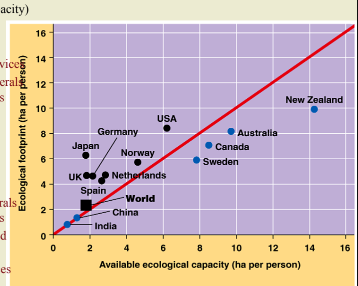
- **Ecological Footprint** = land per person needed to support resource demands
- US footprint is 10X the India footprint
- Countries above the mid-line are in ecological deficit (above carrying capacity)



Ecological footprint vs. ecological capacity

Ecological Footprint

- Countries above the mid-line are in ecological deficit (above carrying capacity)
- United States
  - 4.7% of the world population
  - Produces 21% of all goods and services
  - Uses 25% available processed minerals and nonrenewable energy resources
  - Generates at least 25% of world's pollution and trash
- India
  - 17% of the world population
  - Produces 1% goods and services
  - Uses 3% available processed minerals and nonrenewable energy resources
  - Generates 3% world's pollution and trash
- U.S. consumes 50 times more resources than India (per person)
- US footprint is 10X the India footprint



Ecological footprint vs. ecological capacity

Your Personal Footprint!

- The overpopulation and overconsumption by the human population are triggering an enormous array of problems, ranging from food sources (agriculture, fisheries), waste, air and water pollution, energy and mineral use, habitat destruction, and species extinction. You can calculate your own ecological footprint by going to the following URL:
  - http://www.myfootprint.org/