Lecture 17, 18 October 2005
Populations, CH7, PVA, MVP

Conservation Biology
ECOL 406R/506R
University of Arizona
Fall 2005

Kevin Bonine
Kathy Gerst

1

Conservation Biology 406R/506R

1. Populations (Ch7)
2. Thank Kathy Gerst

LAB+: Field Trip Friday –> Sunday, 21-23 October
(check your email, meet 0645am Friday morning!)

2

AZDStar
18 Oct 2005

# Some nations would love to pay $3 a gallon for gas

THE ASSOCIATED PRESS

WASHINGTON — Americans are grumbling about gas prices hovering around $3 a gallon, but that price would be welcome in many other countries.

AP-Ipsos polling found wide disparities in what people in the United States and eight other countries think is a fair price.

Americans grit their teeth as they pump $3-per-gallon gas. They think $2 is about right. In Britain, $3 sounds sweet — people there pay about $6.40 a gallon and think $5 would be fair.

Spaniards would like to see gasoline for just over $3 a gallon. People in France, Italy, Germany and South Korea put the fair market price at $4 or a little more. Australians and Canadians would like to see it just under $3 a gallon. The cost of gas in these countries is higher than in the United States — from just over $4 a gallon in Australia to about $6.70 a gallon in Germany.

Americans' desire for cheap

AP-IPSOS POLL

## U.S. expects inexpensive gas

Compared to other countries, the United States expects to pay far less for a gallon of gasoline.

| | What would you say is a fair price for a gallon of gasoline? | Over the next six months, do you expect that increases in the price of gasoline will cause financial hardship for you or your family? |
|---|---|---|
| U.S. | $1.99 | 69% |
| Canada | $2.72 | 65% |
| Australia | $2.94 | 63% |
| Spain | $3.32 | 67% |
| Italy | $4.05 | 74% |
| France | $4.08 | 77% |
| S. Korea | $4.11 | 85% |
| Germany | $4.87 | 31% |
| U.K. | $5.18 | 52% |

SOURCE: Ipsos for AP

Ahrens, a businessman from Dows, Iowa. Most Americans, he said, have come to expect it over the years.

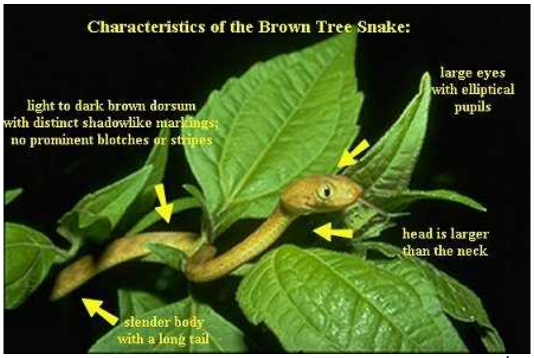
In much of Europe and elsewhere, gas taxes account for two-thirds or more of the price

and politicians talk about increasing gas taxes — or any taxes — at their own risk.

"We do have a sense of entitlement here in the United States," said Steve Yetiv, a political scientist at Old Dominion Univer-

3

http://www.fort.usgs.gov/resources/education/bts/bts_home.asp

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http://www.fort.usgs.gov/resources/education/bts/bts_home.asp


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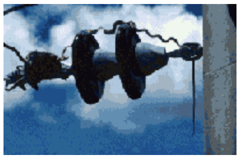
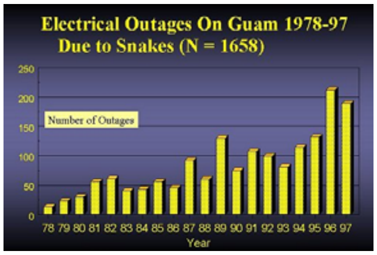
http://www.fort.usgs.gov/resources/education/bts/bts_home.asp





http://www.fort.usgs.gov/resources/education/bts/bts_home.asp

The hand of an infant with swelling, discoloration, and bleb formation.

Results of one night's captures by hand.

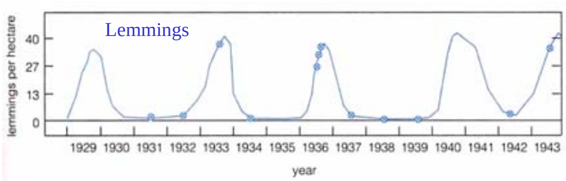
7

## What is population viability analysis? (PVA)

Thanks to Margaret Evans, 2003

8

populations are dynamic, not static

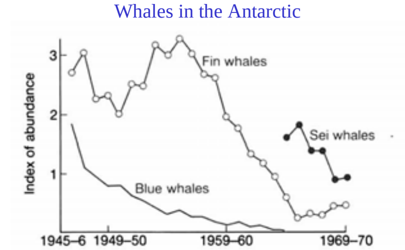



Cause of cyclic change in population not completely understood. Cycle length average 3.8 years Mass migration in response to high density with decreasing food supply, sometimes swimming involved.

9

populations are dynamic, not static

Whales in the Antarctic

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## Population sizes change over time

Why?
What causes change in population size?
What regulates population size?

If we can answer these questions, we might be able to make changes that increase populations of declining (endangered) species

11

## Many things affect population size

population size

population structure

competition
within a species
among species

other interactions
predation, herbivory, pollination, etc.

chance events
demographic
genetic

environmental variation
good years, bad years

habitat attributes
quantity, quality, configuration, and connectivity

succession or disturbance

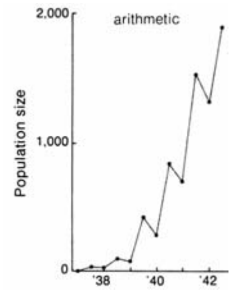
12

# 1. Exponential growth

density-independent, deterministic

In a closed population (no immigration or emigration), population growth is a function of birth and death rates

$$\frac{dN}{dt} = (b-d)N$$

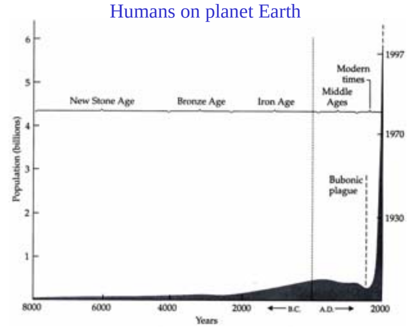



Ring-necked pheasant on Protection Island

13

exponential growth: an unrealistic model?

Humans on planet Earth




14

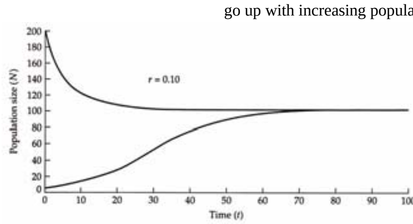
# 2. Logistic growth

density-dependent, deterministic

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

intraspecific competition stabilizes population size

birth rates go down and/or death rates go up with increasing population size

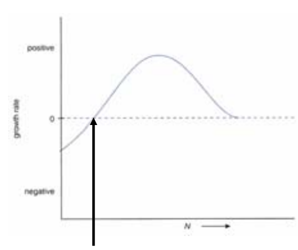



carrying capacity (K)

15

Alternatively,
The population growth rate may increase with population size (positive density-dependence)

Allee effect




minimum viable population size

16

# Allee effect

How?

**In animals:**
- -group defense against predators
- -group attack of prey
- -mates difficult to find
- -critical number to stimulate breeding behavior

**In plants:**
- -pollinator limitation
- -self-incompatibility
- -inbreeding depression


# Allee effect

How?

group defense against predators

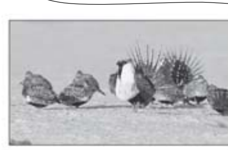


Figure 7.6 The sage grouse (Centrocercus urophasianus), a gallinaceous bird of the western United States, gathers for mating on communal display and breeding grounds known as leks. If numbers are insufficient to promote lek formation, displays and breeding may not take place.

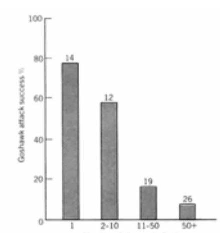



**FIGURE 13.17 Success rate of goshawk attacking pigeons in flocks.**
Attack by a trained goshawk rarely resulted in capture of a pigeon from a large flock, although most attacks on single pigeons were successful.

.3

The two categories of models we have considered thus far assume that

- all individuals in a population have the same birth and death rates
  (no genetic, developmental, or physiological differences among individuals)

  under some circumstances, this might cause us to inaccurately predict population size



## 3. Structured population models

density-independent, deterministic

This is the type of model most often used in population viability analysis

### What is meant by "structure"?

A population is **unstructured** if all individuals have the same rates of survival and fertility.

A population is **structured** if differences among individuals in **age**, developmental **stage**, or **size** cause them to have different survival or fertility rates.



**TABLE 6.3 Survival data for red-cockaded woodpeckers in different reproductive stages, from Walters (1990)**

| *Stage* | *Total number of bird-years* | *Fate at the end of a one-year interval* *Dead* | *Alive* | *Proportion surviving one year* |
|---|---|---|---|---|
| Fledglings | 616 | 345 | 271 | 0.44 |
| Solitary males | 131 | 50 | 81 | 0.62 |
| Helpers-at-the-nest | 273 | 60 | 213 | 0.78 |
| Breeding males | 838 | 201 | 637 | 0.76 |
| Floaters | 29 | 11 | 18 | 0.62 |

Life Tables



**Table 7.1 A Life Table for Belding's Ground Squirrel (*Spermophilus beldingi*).** Life tables, properly constructed from appropriate data, provide important summaries of age-specific demographic characteristics of plant and animal populations: *n* is the actual number of individual squirrels alive in each age interval; *d* is the number dying during the interval; *l* is the proportion of the original cohort alive at the beginning of the age interval; *q* is the mortality rate from interval *x* to interveral *x* + 1; *e* is the life expectancy of individuals in the age interval; and *x* is the age interval to which the value refers. Calculations of *l* do not include individuals first marked as adults.

| | FEMALES | | | | | MALES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| AGE (YEARS) | $n_x$ | $d_x$ | $l_x$ | $q_x$ | $e_x$ | $n_x$ | $d_x$ | $l_x$ | $q_x$ | $e_x$ |
| 0–1 | 337 | 207 | 1.000 | 0.61 | 1.33 | 349 | 227 | 1.000 | 0.65 | 1.07 |
| 1–2 | 252* | 125 | 0.386 | 0.50 | 1.56 | 248† | 140 | 0.350 | 0.56 | 1.12 |
| 2–3 | 127 | 60 | 0.197 | 0.47 | 1.60 | 108 | 74 | 0.152 | 0.69 | 0.93 |
| 3–4 | 67 | 32 | 0.106 | 0.48 | 1.59 | 34 | 23 | 0.048 | 0.68 | 0.89 |
| 4–5 | 35 | 16 | 0.054 | 0.46 | 1.59 | 11 | 9 | 0.015 | 0.82 | 0.68 |
| 5–6 | 19 | 10 | 0.029 | 0.53 | 1.50 | 2 | 0 | 0.003 | 1.00 | 0.50 |
| 6–7 | 9 | 4 | 0.014 | 0.44 | 1.61 | 0 | — | — | — | — |
| 7–8 | 5 | 1 | 0.008 | 0.20 | 1.50 | — | — | — | — | — |
| 8–9 | 4 | 3 | 0.006 | 0.75 | 0.75 | — | — | — | — | — |
| 9–10 | 1 | 1 | 0.002 | 1.00 | 0.50 | — | — | — | — | — |

Source: Sherman and Morton 1984.
*Includes 122 females first captured as yearlings.
†Includes 126 males first captured as yearlings.

## 3. Density-independent, deterministic, structured population growth

What else can structured population models tell us?

### Sensitivity

The sensitivity of $\lambda$ to each matrix element describes how much $\lambda$ will be affected by a change in that transition probability

Would it be better to focus conservation efforts on improving the survival of hatchlings or large juveniles or adults???

(Lambda = population growth rate)



When *lambda* is **greater** than 1 the population **increases** in size

When *lambda* is **less** than 1 the population **decreases** in size

3. Density-independent, deterministic, structured population growth

What else can structured population models tell us?

**Elasticity**

Elasticities quantify the proportional change (e.g., 1%) in the asymptotic growth rate that can be expected given a particular change (1%) in each life history transition.



Van Dyke p. 178

“Four Horsemen of the Extinction Apocalypse:”

1. Genetic Stochasticity
2. Environmental Stochasticity
3. Demographic Stochasticity
4. Natural Catastrophes



**Evolution of Population Viability Assessments for the Florida Panther: A Multiperspective Approach**
*David S. Maehr, Robert C. Lacy, E. Darrell Land, Oron L. Bass Jr., and Thomas S. Hoctor*

IN: Population Viability Analysis. Steven R. Beissinger and Dale R. McCullough, eds. Univ. of Chicago Press, Chicago. xvi + 577 pps.



-Panther Article on PVAs over time

-VORTEX
-data
-population size?
-source and sink?
-inbreeding problems?
-captive breeding?
-introgression?
-time scale?
-HABITAT LOSS

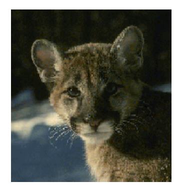




Table 14.1 Comparison of VORTEX Model Inputs Provided Independently by the Five Authors and the Outputs Generated from These Simulations

| Model Inputs and Output | Originator of Variable Estimates for the VORTEX Simulation: Population Ecologist (Lacy) | State Field Biologist (Land) | Federal Field Biologist (Bass) | University Landscape Ecologist (Hoctor) | University Conservation Biologist (Maehr) |
|---|---|---|---|---|---|
| *Inputs* | | | | | |
| Inbreeding depression? | Yes | No | No | No | No |
| Lethal equivalents | 3.14 | — | — | — | — |
| % due to recessive lethals | 50 | — | — | — | — |
| Reproduction correlated with survival? | Yes | No | No | No | No |
| Polygynous mating system? | Yes | Yes | Yes | Yes | Yes |
| Age 1st female reproduction | 2 | 1 | 3 | 2 | 2 |
| Age 1st male reproduction | 4 | 3 | 2 | 3 | 3 |
| Maximum individual age | 12 | 12 | 12 | 9 | 12 |
| Reproduction density dependent? | No | No | No | No | No |
| Sex ratio at birth | 50:50 | 50:50 | 50:50 | 50:50 | 50:50 |
| Maximum litter size | 4 | 4 | 2 | 3 | 4 |
| % females with litter/year | 50 | 50 | 50 | 60 | 50 |
| SD of above | 20 | 5 | 10 | 10 | 5 |
| % litter of size 1 | 32.5 | 17.5 | 50 | 20.0 | 10.0 |
| % litter of size 2 | 40.0 | 50.0 | 50 | 50.0 | 50.0 |
| % litter of size 3 | 20.0 | 30.0 | — | 30.0 | 30.0 |
| % litter of size 4 | 7.5 | 2.5 | — | 0 | 10.0 |
| Female mortality in year 1 | 26.5 | 20 | 0 | 20 | 20 |
| SD in female mortality, year 1 | 6.625 | 2.0 | 4 | 10.0 | 5.0 |
| Female mortality in year 2 | 10.1 | — | 0 | 10 | 20 |



Table 14.1 (continued)

| Model Inputs and Output | Originator of Variable Estimates for the VORTEX Simulation: Population Ecologist (Lacy) | State Field Biologist (Land) | Federal Field Biologist (Bass) | University Landscape Ecologist (Hoctor) | University Conservation Biologist (Maehr) |
|---|---|---|---|---|---|
| Male mortality in adults | 21.7 | 20 | 66 | 20 | 20 |
| SD in male mortality, adults | 5.425 | 3.0 | 6 | 5.0 | 10 |
| Number of catastrophe types | 0 | 0 | 0 | 2 | 1 |
| Probability for catastrophe 1 | — | — | — | 0.05 | 0.02 |
| Probability for catastrophe 2 | — | — | — | 0.01 | — |
| Reproduction rate for catastrophe 1[a] | — | — | — | 0.80 | .98 |
| Reproduction rate for catastrophe 2[a] | — | — | — | 0.50 | — |
| Survival for catastrophe 1[a] | — | — | — | 0.80 | 0.95 |
| Survival for catastrophe 2[a] | — | — | — | 0.50 | — |
| % of adult males breeding | 100 | 50 | 100 | 50 | 40 |
| Starting population size | 50 | 50 | 6 | 60 | 70 |
| Habitat carrying capacity | 50 | 60 | 8 | 70 | 85 |
| SD of above | 0 | 5 | 2 | 10 | 5 |
| Change in habitat | Lost | 0 | 0 | Lost | 0 |
| # of years of habitat loss | 25 | 0 | 0 | 20 | 0 |
| % habitat change per year | −1.0 | 0 | 0 | −1.5 | 0 |
| Will panthers be removed? | No | No | No | Yes | No |
| At what annual interval? | — | — | — | 1 | — |
| For how many years? | — | — | — | 10 | — |
| # males removed/year | — | — | — | 1 | — |
| # females removed/year | — | — | — | 1 | — |
| Population augmentation? | Yes | Yes | Yes | No | No |
| If yes, at what interval? | 20 years | 10 years | 10 years | — | — |
| For how many years? | 100 | 100 | 100 | — | — |
| # males added per event | 0 | 0 | 1 | — | — |
| # females added per event | 6 | 1 | 2 | — | — |
| *Outputs* | | | | | |
| Expected heterozygosity | 0.692 | 0.597 | 0.659 | 0.537 | 0.635 |
| Number of extant alleles | 6.38 | 4.58 | 3.89 | 3.58 | 4.68 |
| Probability of persistence to 100 years over 500 iterations | 0.998 | 1.00 | 0.0680 | .998 | 1.00 |
| Mean final population | 34.19 | 59.41 | 5.52 | 50.24 | 83.29 |
| Median time to extinction | — | — | 7.13 years | — | — |

Note: SD = standard deviation.
[a]These values represent multipliers that reduce survival and reproduction due to catastrophe.

Table 14.2 Comparison of Variables Used in the PVA Models

| Model Inputs and Outputs | 1989 Panther PVA | 1992 Panther PVA Consensus | 1992 Panther PVA Optimistic | 1999 Consensus Simulation |
|---|---|---|---|---|
| *Inputs* | | | | |
| Inbreeding depression? | Yes | Yes | No | Yes |
| Lethal equivalents | 3.4 | 3.0 | 0 | 3.14 |
| % due to recessive lethals | 0 | 0 | 0 | 50 |
| Reproduction correlated with survival? | Yes | Yes | No | No |
| Polygynous mating system? | Yes | Yes | Yes | Yes |
| Age 1st female reproduction | 3 | 2 | 2 | 2 |
| Age 1st male reproduction | 3 | 2 | 2 | 4 |
| Maximum individual age | 15 | 12 | 12 | 12 |
| Reproduction density dependent? | No | No | No | No |
| Sex ratio at birth | 50:50 | 50:50 | 50:50 | 50:50 |
| Maximum litter size | 5 | 3 | 3 | 4 |
| % females with litter/year | 50 | 50 | 50 | 50 |
| SD of above | 1 | 0 | 0 | 10 |
| % litter of size 1 | 10 | 25 | 25 | 17.5 |
| % litter of size 2 | 20 | 50 | 50 | 50.0 |
| % litter of size 3 | 40 | 25 | 25 | 30.0 |
| % litter of size 4 | 20 | — | — | 2.5 |
| % litter of size 5 | 10 | — | — | — |
| Female mortality in year 1 | 50 | 50 | 20 | 20 |
| SD in female mortality, year 1 | 5 | 0 | 0 | 6 |
| Female mortality in year 2 | 30 | 20 | 20 | 20 |
| SD in female mortality, year 2 | 3 | 0 | 0 | 3 |
| Female mortality in year 3 | 25 | — | — | — |
| SD in female mortality, year 3 | 3 | — | — | — |
| Female mortality in adults | 25 | 20 | 20 | 17 |
| SD in female mortality, adults | 3 | 0 | 0 | 3 |
| Male mortality in year 1 | 50 | 50 | 50 | 20 |
| SD in male mortality, year 1 | 5 | 0 | 0 | 6 |
| Male mortality in year 2 | 30 | 20 | 20 | 30 |
| SD in male mortality, year 2 | 3 | 0 | 0 | 5 |
| Male mortality in year 3 | 25 | — | — | 30 |
| SD in male mortality, year 3 | 3 | — | — | 5 |
| Male mortality in adults | 25 | 20 | 20 | 15 |
| SD in male mortality, adults | 3 | 0 | 0 | 5 |
| Number of catastrophes | 2 | 0 | 0 | 1 |
| Probability for catastrophe 1 | 0.01 | — | — | 0.5 |
| Probability for catastrophe 2 | 0.02 | — | — | — |
| Reproduction rate for catastrophe 1 | — | — | — | 0.95 |
| Reproduction rate for catastrophe 2 | — | — | — | — |
| Survival for catastrophe 1 | — | — | — | 0.95 |
| Survival for catastrophe 2 | — | — | — | — |
| % of adult males breeding | 100 | 50 | 50 | 50 |
| Starting population size | 45 | 50 | 50 | 60 |
| Habitat carrying capacity | 45 | 50 | 50 | 70 |
| SD of above | 1 | 0 | 0 | 5 |

(continued)



Table 14.4 Effects of Increasing Carrying Capacity on Genetic Heterozygosity after 100 Years, Using the Consensus VORTEX Simulation

| Carrying Capacity | Predicted Heterozygosity (%)[a] |
|---|---|
| 70 | 72.2 |
| 100 | 80.6 |
| 150 | 84.1 |
| 200 | 86.5 |
| 250 | 87.5 |
| 300 | 89.6 |
| 400 | 90.7 |
| 500 | 92.4 |

[a] As percentage of initial value of $H$.



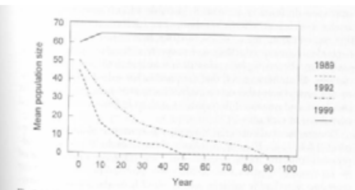



Fig. 14.3 Mean extant population sizes per ten-year intervals for Florida panther PVAs conducted in 1989 and 1992, and the consensus simulation from 1999.

-data

*Evolution of PVA for the Florida Panther* 301

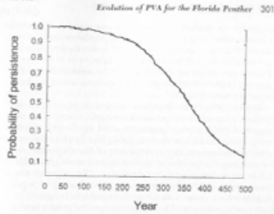



Fig. 14.4 Probability of persistence of the Florida panther based on the consensus simulation run for 500 years.

-time scale?

## Last thoughts on PVA

PVA requires lots of data, which takes time, work, and money, whereas managers want answers (predictions about extinction) now. Few species will get thorough PVA. When should PVA be used and what type of PVA (how complex)?

Predictions from PVA can only be as good as the data that go into the analysis. We can only have degrees of confidence in the predictions from PVA. Populations should not be managed to their "minimum viable population" size.

One of the greatest strengths of PVA is the ability to play "what if" games with the model. That is, what if management were to increase patch sizes or connectivity? What if adult survival were improved?