1

Populations:
Population Ecology

EVPP 110 Lecture
Instructor: Dr. Largen Fall 2003

2 ## Population ecology

- ✓Population
  - – definition
  - – major characteristics
  - – dynamics
  - – life histories

3 ## Population definition

- ✓**Population**
  - – definition
    - group of individuals of a species living in same area at same time
      - – using common resources
      - – regulated by same natural phenomena

4 Figure: Monarch butterflies

5 ## Population definition

- ✓**Population**
  - – definition
    - flexible
    - allows discourse in similar terms about any population
      - –
      - –
      - –

6 Figure: Aerial census for African buffalo (*Syncerus caffer*) in the Serengeti of East Africa

7 ## Population characteristics

- ✓**Populations**
  - – major characteristics
    - size
    - density
    - dispersion
    - age distribution

8 ## Population characteristics

- ✓**Population size**
  - – definition

- number of individuals

– important feature of any population

9 ☐ Population characteristics

✓ **Population size**

– affects ability of population to survive

- small populations tend to become extinct
  - endangered by random events
  - inbreeding
    - »
    - »

10 ☐ Population characteristics

✓ **Population density**

– definition

- number of individuals in a certain area or volume
  - # trees per km^2 of forest
  - # earthworms per m^3 of soil

11 ☐ Population characteristics

✓ **Population density**

– important to survival of population

- individuals spaced widely apart may rarely encounter one another
  - limits reproductive capacities
    - »

12 ☐ Population characteristics

✓ **Population density**

– how is population density measured?

- impossible or impractical to count all individuals in a population
  - –
  - –
- use **sampling techniques**

13 ☐ Population characteristics

✓ **Population density**

– **sampling technique**

- method to <u>estimate</u> population density
  - direct count of organisms or indicators in small area or volume
    - » used to project actual density over entire area or volume
  - examples
    - »
    - »

14 ☐ Population characteristics

✓ **Population dispersion**
- way in which individuals of a population are spaced within their area or volume
  - often depends on resource availability
- spatial pattern
  - three main patterns of dispersion
    - **clumped**
    - **uniform**
    - **random**

15 ## Population characteristics

✓ **Population dispersion**
- **clumped**
  - individuals clump into groups or clusters
  - often in response to uneven distribution of resources
    -
    -
  - most common pattern in nature

16

17

18 

Figure: Clumped dispersion: buffalo, swans, fish, lupine

19 ## Population characteristics

✓ **Population dispersion**
- **uniform**
  - individuals are uniformly or evenly spaced
  - often results from interactions between individuals
    -
    -
  - relatively common in nature

20

21

22 ## Population characteristics

✓ **Population dispersion**
- **random**
  - individuals spaced in a pattern-less, unpredictable way
    - don't interact strongly with
      - » one another
      - » non-uniform aspects of their environment
  - not common in nature

23

24

25 ## Population characteristics

✓ **Population age distribution**

- proportions of individuals of each age
- often based on
  - non-reproductive ages
  - reproductive ages
  - post-reproductive ages

26 Population dynamics

✓**Population dynamics**

- variables governing changes in population size
- factors that affect population size
- population growth
  - types of
  - limits to

27 Population dynamics

✓**Population dynamics**

- populations are dynamic
  - size increases or decreases in response to
    - environmental stress
    - changes in environmental conditions

28 Variables governing change in population size

✓**Variables governing change in population size**

- governed by 4 variables
  - births
  - deaths
  - immigration
  - emigration

29 Variables governing change in population size

✓**Variables governing change in population size**

- populations
  - gain individuals by
    - birth
    - immigration
  - lose individuals by
    - death
    - emigration

30 Variables governing change in population size

✓**Variables governing change in population size**

✓population change=(births+immigrations - (deaths+emigration)

31 Factors that affect size of population

✓**Factors that affect size of population**

- population size may increase, remain stable, or decrease

- depending on interactions between
  - **biotic potential**
    - » growth factors
  - **environmental resistance**
    - » decrease factors

32 Factors that affect size of population

✓ **Factors that affect size of population**

- **biotic potential**
  - “growth factors”
  - capacity of a population for growth
  - varies
    - between populations
    - within population over time

33 Factors that affect size of population

✓ **Factors that affect size of population**

- **biotic potential**
  - factors that favor increase in size
    - abiotic
      - » favorable light
      - » favorable temperature
      - » favorable chemical environment (optimal level of critical nutrients)

34 Factors that affect size of population

✓ **Factors that affect size of population**

- **biotic potential**
  - factors that favor increase in size
    - biotic (such as)
      - » high reproductive rate
      - » generalist
      - » adequate food
      - » adequate defenses from predators
      - » resistance to diseases

35 Factors that affect size of population

- ✓ **Factors that affect size of population**
  - – **environmental resistance**
    - • “decrease factors”
    - • all the factors acting jointly to limit growth of a population

36 Factors that affect size of population

- ✓ **Factors that affect size of population**
  - – **environmental resistance**
    - • factors that lead to decrease in size
      - – abiotic
        - » too much, too little light
        - » temperature too high, too low
        - » unfavorable chemical environment (critical nutrients too high, too low)

37 Factors that affect size of population

- ✓ **Factors that affect size of population**
  - – **environmental resistance**
    - • factors that lead to decrease in size
      - – biotic (such as)
        - » low reproductive rate
        - » specialist
        - » inadequate food
        - » inadequate defenses from predators
        - » inability to resist diseases

38 Factors that affect size of population

- ✓ **Factors that affect size of population**
  - – biotic potential & environmental resistance
    - • together determine
      - – **carrying capacity (K)**
        - » number of individuals of a given species that can be sustained indefinitely in a given area or volume

39 ☐ Types of population growth

✓ Two types of population growth
- **exponential**
  - accelerating increase in population size
    - occurs when growth is unregulated
- **logistic**
  - population growth that is slowed by population-limiting factors
    - tends to level off at a carrying capacity

40 ☐ Types of population growth

✓ **population growth**
- two types
  - **exponential**
  - **logistic**

41 ☐ Types of population growth

✓ **Exponential growth**
- exhibited by a population that has few, if any, resource limitations
- starts out slowly, speeds up as population increases
- rate of expansion that occurs under ideal conditions
- entire population multiplies by a constant factor during constant time intervals

42 ☐ Types of population growth

✓ **Exponential growth**
- described by equation $G = rN$
  - G = growth rate of the population
  - N = population size
  - **r = intrinsic rate of increase**
- graph produces typical J-shaped curve

43 ☐ Types of population growth

✓ **Exponential growth**
- **r = intrinsic rate of increase**
  - rate at which a population would grow if it had unlimited resources
    - remains constant for any population expanding without limits
  - based on organism's inherent capacity to reproduce
    - varies by organism

44 ☐ Types of population growth

✓ **Exponential growth**
- **r = intrinsic rate of increase**
  - can be roughly estimated as
    - birth rate minus death rate
    - $r = b - d$

45 ☐ Types of population growth

✓ **Exponential growth**

– long periods of exponential growth are <u>not</u> common

• bacteria example

–

46 Types of population growth

✓ **Exponential growth**

– no population can grow indefinitely

• eventually some factor(s) limit population growth

– rapidly growing population reaches size limit imposed by shortage of limiting factors

» *there are always limits to population growth in nature*

47 Figure: Population growth predicted by the exponential model

48 Types of population growth

✓ **Logistic growth**

– growth, slowed by limiting factors

– involves

• exponential growth when pop. is small

• steady ↓ in growth with time as pop.

– encounters environmental resistance

– approaches carrying capacity

49 Types of population growth

✓ **Logistic growth**

– equation must account for limiting factors

• exponential equation is modified by a term that represents overall effect of limiting factors

– (K - N)/K where K = **carrying capacity**

50 Types of population growth

✓ **Logistic growth**

– effects of the modifying term

• (K - N)/K

– when population is small,

» (K - N)/K has little effect

» growth rate is reduced very little

» early logistic curve is very similar to J-shaped exponential curve

• for example, if N=10 and K=1000

– (1000-10)/1000 = 0.99

51 Types of population growth

✓ **Logistic growth**

– as population gets larger,

• (K - N)/K has greater effect

• growth rate is affected more (gets smaller)

- later logistic curve becomes S-shaped
  - population levels off at “carrying capacity”
    - » limiting factors causes birth rate and death rate to be equal
- for example, N= 800 and K=1000
  - (1000-800)/1000 = 0.20

52 Table : A Hypothetical Example of Logistic Population Growth, Where K=1,000 and r_{max}=0.05 per Individual per Year

53 Types of population growth

✓ **Logistic growth**

- after leveling off at carrying capacity (K)
  - population typically fluctuates slightly above or below K

54

55

56 Types of population growth

✓ **Exponential and logistic growth models**

- both are mathematical ideals
- no natural populations fit either model perfectly

57 Limits to population growth

✓ **Population growth**

- **limited** by two general types of factors
  - **density-dependent factors**
    - limits to growth related to population density
  - **density-independent factors**
    - limits to growth **not** related to population density

58 Limits to population growth

✓ **density-dependent factors**

- affect a greater percentage of individuals in a population as density increases
  - individuals compete with increasing intensity for limited resources
    - such as
      - » food
      - » shelter
      - » light

59 Limits to population growth

✓ **density-independent factors**

- population-limiting affects that are <u>independent</u> of population density
- include abiotic factors
  - weather
  - physical disruption of habitat

60 Population fluctuations

✓ **Population fluctuations**

- occur in nature, over time
  - four general types exist
    - **stable**
    - **irruptive**
    - **irregular**
    - **cyclic**
- most are poorly or incompletely understood

61 Population fluctuations

✓**Population fluctuations**

- **stable**
  - population size fluctuates around carrying capacity
    - slightly above
    - slightly below
  - typical of species in undisturbed tropical rainforests
    - little variation in average temperature or rainfall

62 Population fluctuations

✓**Population fluctuations**

- **irruptive**
  - population is normally fairly stable
  - occasionally explodes (*irrupts)* to peak
    - then crashes to
      - » stable lower level
      - » very low level
    - due to factor (ie temp) that temporarily increases carrying capacity
  - examples: raccoon, house mouse

63 Population fluctuations

✓**Population fluctuations**

- **irregular**
  - irregular, chaotic behavior in population size
    - no apparent recurring pattern
  - may be due to
    - chaos in system
    - poorly understood interactions

64 Figure: Irregular population fluctuations

65 Population fluctuations

✓**Population fluctuations**

- **cyclic**
  - fluctuations in size that occur over a regular time period
  - most are poorly understood
  - include **predator-prey cycles**

66 Population fluctuations

✓ **Population fluctuations**
- **predator-prey cycles**
  - seen in some groups of species that interact as predator and prey
    - characterized by
      - » sharp increases in numbers followed by
      - » seemingly periodic crashes
    - classic example
      - » snowshoe hare, Canadian lynx

67 Figure: snowshoe hare and lynx

68 Population fluctuations

✓ **Population fluctuations**
- **predator-prey cycles**
  - explained by two hypotheses
    - top-down control
    - bottom-up control

69 Population fluctuations

✓ **Population fluctuations**
- **predator-prey cycles**
  - top-down control hypothesis
    - lynx prey on hare
    - reduces hare population
    - fewer hares support fewer lynxes
    - causes periodic reduction in lynx population
      - » lag-time, offset from hare reduction

70 Population fluctuations

✓ **Population fluctuations**
- **predator-prey cycles**
  - top-down control hypothesis *cont*
    - reduced numbers of predators (lynx) allows population of prey (hare) to recover and increase
    - increased numbers of prey (hare) support increased numbers of predators and lynx population increases
    - cycle continues

71 Population fluctuations

✓ **Population fluctuations**
- **predator-prey cycles**
  - top-down control hypothesis *cont*
    - doubt has been cast on this explanation
      - » snowshoe hares have been found to exhibit similar 10-year “boom-or-bust” cycles on islands where lynx are absent
    - leading to 2nd hypothesis
      - » bottom-up control

72 Population fluctuations

✓ **Population fluctuations**
- **predator-prey cycles**
  - bottom-up control hypothesis
    - rather than cycle being driven by predator at top
      - » might be driven by food source of prey (hare) at bottom

73 Population fluctuations

✓ **Population fluctuations**
- **predator-prey cycles**
  - bottom-up control hypothesis *cont*
    - reduction in quantity or quality of food source (plants) of hare leads to crash of hare population
    - fewer hare support fewer predators and lynx population crashes
    - reduction in hare population gives plant population time to recover

74 Population fluctuations

✓ **Population fluctuations**
- **predator-prey cycles**
  - bottom-up control hypothesis *cont*
    - increased plant population supports more hares and hare population increases
    - increased hare population supports more lynx and lynx population increases
    - cycle continues, driven by plant availability

75 Population fluctuations

✓ **Population fluctuations**
- **predator-prey cycles**
  - genuine examples of both top-down and bottom-up control exist in nature

76 Figure : Population cycles of the snowshoe hare and lynx

77 Survivorship and Life History Strategies

78 **Survivorship and life history strategies**

✓ **Survivorship and life history strategies**
- survivorship
  - life tables
  - survivorship curves
- life history strategies
  - opportunisitc life history
  - equilibrial life history

79 **Survivorship**

✓ **Survivorship**
- percentage of an original population that survives to a given age
  - requires compilation of data (**life table**)
    - for each defined age interval
      - » number living at start of interval

» number dying during interval
– from which can be calculated
» mortality (death rate)
» chance of surviving age interval

80 Table: Life Table for Belding Ground Squirrels (*Spermophilus beldini*) at Tioga Pass, in the Sierra Nevada Mountains of California

81 Survivorship

✓ **Survivorship curves**

– way to express age distribution characteristics of a population
• graph of life table data
– varies with species
– uses percentage scale instead of actual life span on horizontal axis
• allows comparison of species with different life spans on same graph
– three primary types of survivorship curves
• **type I , type II, type III**

82 Survivorship curves

✓ **Survivorship curves**

– three primary types
• **type I survivorship curve**
• **type II survivorship curve**
• **type III survivorship curve**

83 Survivorship curves

✓ **type I survivorship curve**

– exhibited by population in which mortality rates rise steeply in post-reproductive years
• also known as “late loss” curve
– most individuals die in older age intervals
– species with this type curve
• produce few offspring & give them intense care to insure their survival
– examples
• humans, whales, elephants

84

85 Survivorship curves

✓ **type II survivorship curve**

– exhibited by population in which individuals are equally likely to die at any age
• also known as “constant loss” curve
– mortality is constant over life span
– intermediate to types I and III
– examples
• jellyfish
• hydra
• some rodents

86

87 ## Survivorship curves

- ✓ **type III survivorship curve**
  - – exhibited by population in which individuals produce vast numbers of offspring
    - • also known as “early loss” curve
    - • only a small number of offspring survive to reproductive age
      - – survivors become established, reproductive, with low mortality rate
  - – examples
    - • oysters, some plants

88

89 ## Life History Strategies

- ✓ **Life history** of an organism
  - – series of events from birth through reproduction to death
  - – **life history strategies** influence growth rate of a population, including
    - • age of first reproduction
    - • number of offspring
    - • amount of parental care given to offspring
    - • energy cost of reproduction

90 ## Life History Strategies

- ✓ **life history strategies**
  - – shaped by evolution
    - • operating through natural selection
  - – every population has a life history strategy adapted to its environment
  - – two main life history strategies
    - • **opportunistic (r-selected)**
    - • **equilibrial (K-selected)**

91 ## Life History Strategies

- ✓ **Opportunistic (r-selected) life history**
  - – put most of their energy into reproduction
    - • rather than long term survival of individuals
  - – are poor competitors

92 ## Life History Strategies

- ✓ **Opportunistic (r-selected) life history**
  - – considered *opportunists*
    - • take advantage of favorable conditions, changes in environment
      - – when favorable conditions are gone population may crash
        - » population go through irregular or unstable cycles

93 ## Life History Strategies

- ✓ **Opportunistic(r-selected) life history**
  - – characteristics
    - • organisms
      - – small-bodied

- reproduce when young
- produce many offspring
- provide little to no parental care of offspring
- most offspring die before reaching reproductive age

94 Life History Strategies

✓ **Opportunistic(r-selected) life history**

- characteristics
  - populations
    - tends to grow exponentially
      - » thus the name r-selected
      - » due to high intrinsic rate of growth
    - live in unpredictable environments
    - controlled by density-independent factors
    - exhibit type III survivorship curve

95 Life History Strategies

✓ **Opportunistic(r-selected) life history**

- examples
  - bacteria
  - algae
  - most annual plants
    - dandelions
  - most insects
    - cockroaches
  - rodents
  - oysters

96

97

98 Life History Strategies

✓ **equilibrial (K-selected) life history**

- put fairly little energy into reproduction
  - put most energy into long term survival
    - for purpose of being able to put lots of energy into nurturing and protecting offspring
- are good competitors

99 Life History Strategies

✓ **Equilibrial (K-selected) life history**

- are <u>not</u> considered opportunistic
  - thrive best in ecosystems with fairly constant environmental conditions
    - populations remain close to carrying capacity (K) over long periods of time

100 Life History Strategies

✓ **equilibrial (K-selected) life history**
- characteristics
  - organisms
    - larger-bodied
    - reproduce later in life
    - produce fewer offspring
    - provide high parental care
    - most offspring survive to reproductive age

101 ☐ Life History Strategies

✓ **Equilibrial (K-selected) life history**
- characteristics
  - populations
    - size tends to be stable
      - » thus the name K-selected
      - » populations tends to stay near carrying capacity (K)
    - live in predictable environments
    - controlled by density-dependent factors
    - exhibit type I survivorship curve

102 ☐ Life History Strategies

✓ **Equilibrial (K-selected) life history**
- examples
  - humans
  - large trees
  - polar bears
  - elephants

103 

104 ☐ Life History Strategies

✓ **Intermediate life history**
- many organisms have life histories that fall between opportunistic and equilibrial
  - exhibit type II survivorship curve
  - examples
    - many birds
    - squirrels
    - hydra

105 ☐ The End.