

Introduction to Populations



What is a Population?

- Group of organisms of the same species occupying a particular space at the same time
- Population characteristics tell us how a population functions in the environment
- Population Ecology?

Properties of Populations

- Individual units versus Modules
- Animal populations are easily defined as individual units → Unitary
 - Deer, rabbits, cows, bees, spiders, etc.
 - Each individual is a unit of the population
- What about the trees that surround them?
Can we easily define them as units?

Properties of Populations

- Plants: Can we easily define them as units?
 - Every stem, branch, twig, flower, or fruit is part of a larger unit or module
 - Module = part of the whole
- Not only restricted to plants → sponges, corals, hydroids are modular groups (colonies)



Thus we can define populations as unitary (individuals) or modular (groups)

Metapopulations

- Few species populations are continuous (most separated or patchy)
- If patches are close they can act as a single population
- If patches are widely separated and subpopulations are isolated → **metapopulations** (R. Levins, 1969)
 - Each with its own population dynamics
 - Interconnected through immigration



Metapopulations

- Assumptions (from Levins concept)
 - Each population has own birth rate and death rate (independent)
 - Limited dispersal links
 - Finite lifetime
 - Patches similar in size and shape
 - Continually favorable
 - Equally accessible
- Has evolved to include (embrace) less restrictive assumptions

Types of metapopulations:

- A) Classic Levins
- B) Mainland - island
- C) Patchy population
- D) non-equilibrium
- E) intermediate (combines a - d)

Successful movement from one to the next influenced by distance and the surrounding habitat.
Vacant patches → colonized

Important when dealing with fragmented habitats and conservation of species

Benjamin Cummings, an imprint of Addison Wesley Longman

Metapopulations

- Populations as genetic units
 - Each individual carries a certain combination of genes
 - Important → FITNESS!!!
 - **Gene pool** → the sum of all genetic information carried by an interbreeding population
 - **Gene flow** → exchange of genetic information between populations
 - Immigration and Emigration

Density and Dispersion

- **Density** → the size of a population in relation to a definite unit of space
 - Example:
 - Wildlife biologists → number of game animals in a particular area
 - Forester → number and volume of trees in timber stand
 - The measure of the number of individuals per unit area is called **crude density**

Density and Dispersion

- Not all the space within a given unit is occupied by populations
 - Examples:
 - Soil sample contains 2 million arthropods per m², but they only occupy the pore spaces
 - Wildlife area estimated to have 10 deer per square mile, but deer avoid half the area due to human habitation, lack of food, or lack of cover
 - Density measured in terms of the amount of area available as living space is **ecological density**
 - Rarely measured (difficult to determine)

Density and Dispersion

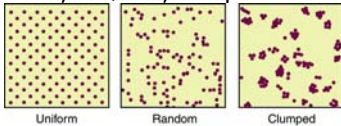
- Density is one of the most important parameters of populations
- Provides basis for speculation:
 - Species position in a food chain
 - Life history strategy
 - Possible stress on a population
 - Susceptibility to extinction, disease, etc.
- Determined by:
 - Energy flow
 - Resource availability
 - Resource utilization
 - Physiological stress
 - Dispersal and Productivity

Density and Dispersion

- Patterns of dispersal
 - Density tells us little about how individuals are allocated over space and time
 - Determining dispersion is a major field problem:
 - Spatial
 - Temporal
 - Movements

Density and Dispersion

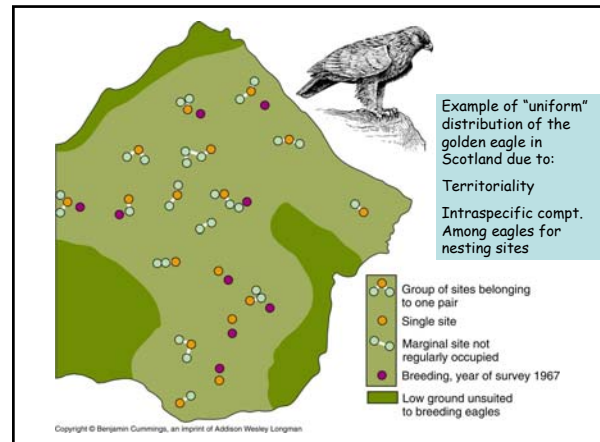
- Patterns of dispersal
- Spatial dispersion:
 - Random, Uniform, Clumped



Random → each individual independent of each other (rare) resources not

Uniform → individuals spaced evenly throughout the environment (territoriality among members → intraspecific competition)

Clumped → (most common); Due to responses to habitat differences



Density and Dispersion

- Patterns of dispersal
- Temporal dispersion:
 - Circadian (diurnal vs. nocturnal)
 - Seasonal movements
 - Responses to the environment
 - Temperature & moisture
- Dispersal Movements
 - Immigration, emigration, migration

Density and Dispersion

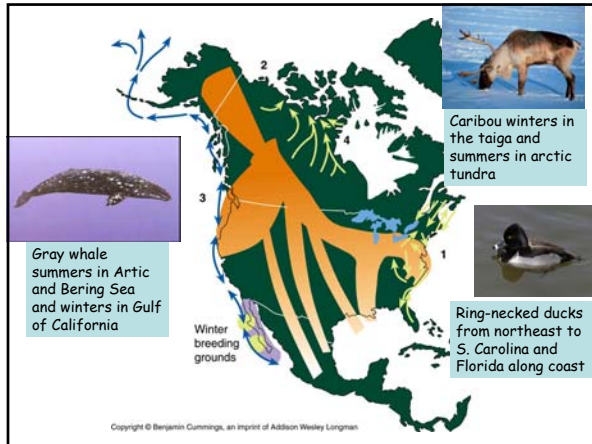
- Dispersal Movements
 - Emigration → moving out
 - Immigration → moving in
 - Migration → just moving, but with a return ticket

Density and Dispersion

- Dispersal Movements
- Passive dispersal → plants
 - Gravity
 - Wind
 - Water
 - Animals (hitch a ride)
 - Fur, feathers, coat
 - Gut (digested then deposited)

Density and Dispersion

- Dispersal Movements
- Active dispersal → most animals
 - Natal → dispersal of the young
 - Breeding → dispersal of adults
 - From poor to better reproductive sites
- Many examples → some quite impressive
 - Migratory movements



Density and Dispersion

- More examples of migratory movements

- Pacific salmon (*Oncorhynchus* spp.)



- Monarch butterfly



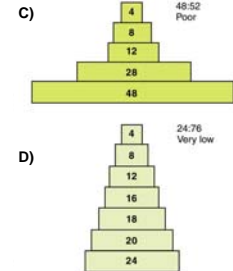
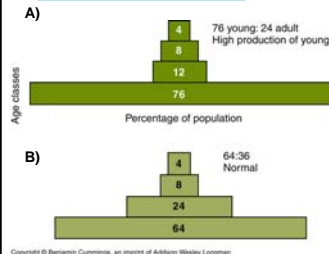
Age Structure

- Age structure (distribution) can help us determine population characteristics:
 - Reproductive rates
 - Death rates
 - Survival
 - Demographic attributes
- Can be determined by time (years, months), by stages (reproductive, pre- or post-reproductive, life stages, etc.) or by size classes
- Differs in animals and plants

Age pyramids:

A - B: typical of growing populations (large number of young) - broad base

C: high proportion in older classes (aging population)



Age pyramids can be useful in looking at population history, but they tell us little about changes in population (increase or decrease)

D: population characterized by older generations, young production low

Sex Ratio

- Proportion of males and females
- Most populations 1:1
 - Primary sex ratio → ratio at conception
 - Secondary sex ratio → ratio at birth
- In mammals, favors males at birth and shifts towards females at older groups
- Among birds it tends to only favor males
- Why?

Sex Ratio

- Why?
- Physiological and behavioral patterns
- Some examples:
 - Elks → males fighting over males (energy consumed; physical burden)
 - Birds → females help defend territory, build nest, lay eggs, broods young, feeds young

Mortality and Natality

- Two main things affecting populations (age structure, growth, etc)
- Mortality (deaths) ↓
- Natality (births) ↑

Mortality and Natality

- **Death rate:** the number of deaths during a given time interval divided by the average population
- **Probability of dying:** number that died during a given time interval divided by the number alive at the beginning of the period
 - Thus the **probability of surviving** would be the opposite:
(# survivors ÷ # alive @ beginning of period)

Mortality and Natality

- Because the number of survivors is more important than the number of dying, mortality is best expressed in terms of **life expectancy**:
 - The average number of years to be lived in the future by members of a given age in the population

Mortality and Natality

- **Natality** (birth of new individuals) is the greatest influence on population increase
 - **Physiological (maximum) Natality:** is the maximum possible # of births under ideal conditions (biological limit per individual)
 - **Realized Natality:** is the amount of successful reproduction that actually occurs over a period of time

Mortality and Natality

- Natality measured as a rate may be expressed as:
 - **Crude Birth Rate:** in terms of population size (50 births/ 1000 population / yr)
 - **Specific Birth Rate:** in terms specific criteria, such as age, individual females, etc.
 - Example: **age-specific schedule of birth** → number of offspring produced per unit time by females in different age classes

The Life Table

- Systematic way of portraying mortality and survival of a given population
- Great tool for managers to assess population dynamics
- Useful when analyzing probabilities of survivorship of individuals, mortality among age classes, and ultimately population growth
- Believe it or not, this is mainly used by insurance companies...but population ecologists have adopted it for studying natural populations

Components of the Life Table

- Note: I don't expect you to memorize these, or to construct a Life Table for test purposes
- $l_x \rightarrow$ known survival
- $d_x \rightarrow$ known death
- $q_x \rightarrow$ proportional mortality (prob. of dying)
- $m_x \rightarrow$ fecundity
- $e_x \rightarrow$ life expectancy
- $R_0 \rightarrow$ Net reproductive rate

Components of the Life Table

- Life Tables consist of series of columns designed to describe an aspect of mortality statistics for members of a population according to age
- Cohort = individuals all born at the same time (week, year, etc.)
- Data for life tables are easy to obtain for laboratory animals and for humans
- Data on age, mortality, and survivorship for organisms in the wild are much more difficult to obtain \rightarrow challenge for managers

TABLE 10.4 Life Table Typical of Sparse Gypsy Moth Populations in Northeastern Connecticut

x	l_x	d_{1x} *	d_x	$100 q_x$
Eggs	550.0	Parasites	82.5	15
		Other	82.5	15
		Total	165.0	30
Instars I-III	385.0	Dispersion, etc.	142.4	37
Instars IV-VI	242.5	Deer mice	48.5	20
		Parasites and disease	12.1	5
		Other	167.3	69
		Total	227.9	94
Prepupae	14.6	Predators, etc.	2.9	20
Pupae	11.7	Vertebrate predators	9.8	84
		Other	0.5	4
		Total	10.3	88
Adults	1.4	Sex (SR = 30:70)	1.0	70
Adult, female	0.4	—	—	—
Generation	—	—	549.6	99.93

X \rightarrow Life stage

$l_x \rightarrow$ known survival

$d_x \rightarrow$ known death

$q_x \rightarrow$ proportional mortality (prob. of dying)

Source: R. W. Campbell 1969.

TABLE 10.5 Life Table for *Phlox drummondii* at Nixon, Texas

Age Interval (days) x - x'	No. Surviving to Day x l_x	Survivorship l_x	No. Dying During Interval d_x	Average Mortality Rate per Day q_x	Mean Expectation of Life (days) e_x
0-63	996	1.0000	328	0.0052	122.87
63-124	668	0.6707	373	0.0092	104.73
124-184	295	0.2962	105	0.0059	137.59
184-215	190	0.1908	14	0.0024	137.05
215-231	176	0.1767	2	0.0007	115.72
231-247	174	0.1747	1	0.0004	100.96
247-264	173	0.1737	1	0.0003	85.49
264-271	172	0.1727	2	0.0017	68.94
271-278	170	0.1707	3	0.0025	62.71
278-285	167	0.1677	2	0.0017	56.78
285-292	165	0.1657	6	0.0052	50.42
292-299	159	0.1596	1	0.0009	45.19
299-306	158	0.1586	4	0.0036	38.46
306-313	154	0.1546	3	0.0028	32.36
313-320	151	0.1516	4	0.0038	25.94
320-327	147	0.1476	11	0.0107	19.55
327-334	136	0.1365	31	0.0325	13.85
334-341	105	0.1054	31	0.0422	9.90
341-348	74	0.0743	52	0.1004	5.58
348-355	22	0.0221	22	0.1428	3.50
355-362	0	0.0000	—	—	—

Source: Leitch and Levin 1978.
Note: As reported in proportion.

Table 3: Life Table for One Darwin Finch, the Galapagos Cactus Finch (*Geospiza scandens*)*

age class (x)	probability of surviving to age x (l_x)	average number of fledgling daughters (m_x)	product of survival and reproduction ($l_x m_x$)
0	1.0	0.0	0.0
1	0.512	0.364	0.186
2	0.279	0.187	0.052
3	0.279	1.438	0.401
4	0.209	0.833	0.174
5	0.209	0.500	0.104
6	0.209	0.833	0.174
7	0.209	0.250	0.052
8	0.209	3.333	0.696
9	0.139	0.125	0.017
10	0.070	0.0	0.0
11	0.070	0.0	0.0
12	0.070	3.500	0.245
13	0	—	—

Net reproductive rate = $R_0 = \sum l_x m_x = 2.101$
 Mean generation time = $T = (\sum x l_x m_x) / R_0 = 6.08$ years
 Intrinsic rate of natural increase of the population = $r =$
 approximately $\ln R_0 / T = 2.101 / 6.08 = 0.346$

*The values are for the cohort of females born in 1975. †Designated in years.
 Source: Adapted from Peter R. Grant and B. Rosemary Grant, "Demography and the Genetically Effective Sizes of Two Populations of Darwin's Finches," *Ecology*, 73(3), 1992, copyright ©1992 The Ecological Society of America, used by permission.

The Life Table

- Important aspect of Life Tables:
- Provides a first indication of population growth from the standpoint of whether or not an individual (usually female) is replacing itself through reproduction
- Provides valuable information for understanding some aspects of how an organism is functioning in its environment
- FITNESS, anyone?

Survivorship and Mortality Curves

- Another important aspect of Life Tables → they can be tools for analysis of population dynamics
- We can derive **survivorship curves** based on the l_x column (known survival)
- Enable us to determine ages @ which a particular organism most often dies
- Provides some leads in determining the cause of death and ultimately the processes that affect population dynamics

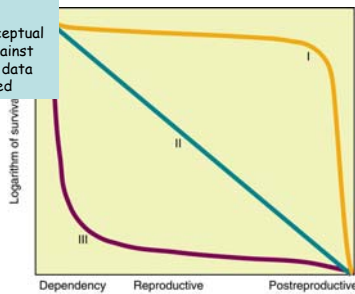
Survivorship and Mortality Curves

- Survivorship curves → depicts age specific mortality
- Obtained by plotting the # of individuals of a particular age cohort over time (usually the logarithms of the # of survivals against age)
- Classified into three hypothetical Types
 - Type I
 - Type II
 - Type III

Survivorship Curves Types I, II, III

NOTE:

These are conceptual models only, against which real-life data can be compared



Type I → Low mortality early in life (parental care) - heavy mortality in old age

Type II → Constant mortality (Ex. - adult birds, rodents, and some plants)

Type III → High mortality early in life - no parental care (Ex. - inverts, fish)

Survivorship and Mortality Curves

- Survivorship curves are useful in comparing the survival characteristics of a population of one area, time, sex, or species with another
- Or in studying the influence of environmental conditions on survival of populations (vulnerability of certain age groups)
- Likewise, **mortality curves** can be useful tools for assessing population dynamics → similar to survivorship curves - plots data in the q_x column (age specific mortality rate - probability of dying)

Animal Natality

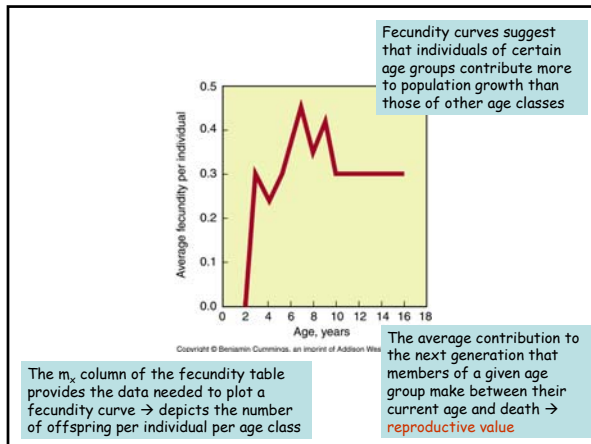
- Remember natality is measured as birth rate or as the number of offspring produced per unit time
- In animals this usually concerns females
 - Thus age-specific birth rate is a function of the total number of females in a population
 - In other words, females giving birth to females
- The age-specific schedule is determined as the mean number of females born in each group (of females)
 - Fecundity (m_x)
- We can use the known survival (l_x) column and the age-specific schedule (m_x) to construct **fecundity tables** (the number of offspring produced per unit time)

TABLE 10.7 Fecundity Table for Red Deer

x	l_x	m_x	$l_x m_x$	$x l_x m_x$
1	1.000	0	0	0
2	0.863	0	0	0
3	0.778	0.311	0.242	0.726
4	0.694	0.278	0.193	0.772
5	0.610	0.308	0.134	0.667
6	0.526	0.400	0.210	1.26
7	0.442	0.476	0.210	1.47
8	0.357	0.358	0.128	1.024
9	0.181	0.447	0.081	0.729
10	0.059	0.289	0.017	0.170
11	0.051	0.283	0.014	0.154
12	0.042	0.285	0.012	0.144
13	0.034	0.283	0.010	0.130
14	0.025	0.282	0.007	0.098
15	0.017	0.285	0.005	0.075
	0.009	0.284	0.003	0.048

Allows us to calculate the net reproductive rate (R_0) → the number of female offspring left during a lifetime by a newborn female

$$R_0 = 1.316$$



Plant Natality

- Germination is the equivalent of birth in plants
- Difficult to estimate (varies from plant to plant → individual to individual)
- Simple cases:
 - Annuals and biennials → one reproductive effort at the end of their life span
- Leverich and Levin (1979)
 - Census of # of seeds produced by different individuals → fecundity schedule for the annual Drummond's phlox
 - Determined R_0 , the net rate of increase (the average number of offspring produced per individual over a lifetime - multiplicative factor with which to obtain the size of the next generation)

TABLE 10.8 Fecundity Schedule for *Phlox drummondii* at Nixon, Texas, Based on Seed Production

$x - x'$	N_x	l_x	m_x^{seed}	$l_x m_x$
0-299	996	1.0000	0.0000	0.0000
299-306	158	0.1586	0.3394	0.0532
306-313	154	0.1546	0.7963	0.1231
313-320	151	0.1516	2.3995	0.3638
320-327	147	0.1476	3.1904	0.4589
327-334	136	0.1365	2.5411	0.3470
334-341	105	0.1054	3.1589	0.3330
341-348	74	0.0743	8.6625	0.6436
348-355	22	0.0221	4.3072	0.0951
355-362	0	0.0000	0.0000	0.0000
				$\Sigma = 2.4177$

$R_0 = \Sigma l_x m_x = 2.42$ (per capita)

$R = \frac{\ln R_0}{365} = 0.0024$ (per capita per day)

Note: $x - x'$ = age interval; N_x = no. surviving to day x ; m_x^{seed} = average no. of seeds per individual during interval; l_x = survivorship; $l_x m_x$ = contribution to net reproductive rate during interval.
Source: From Leverich and Levin 1979.