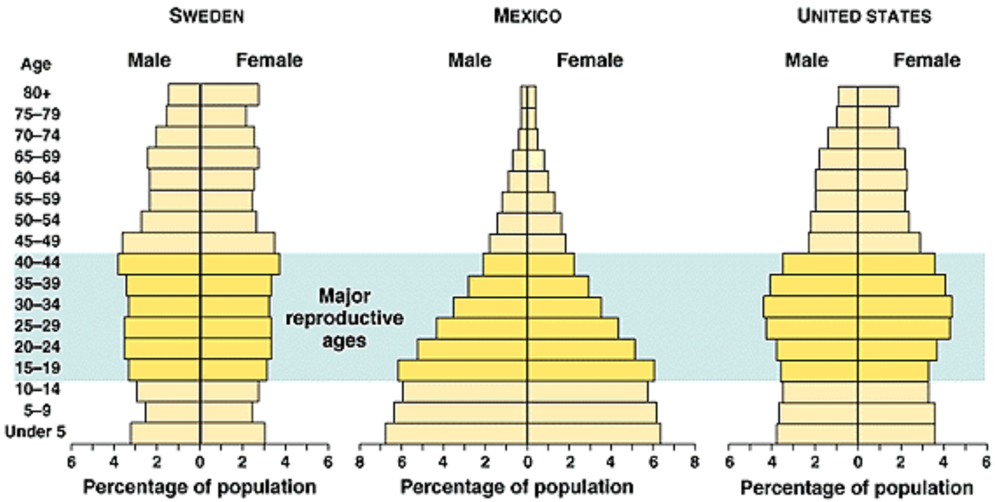
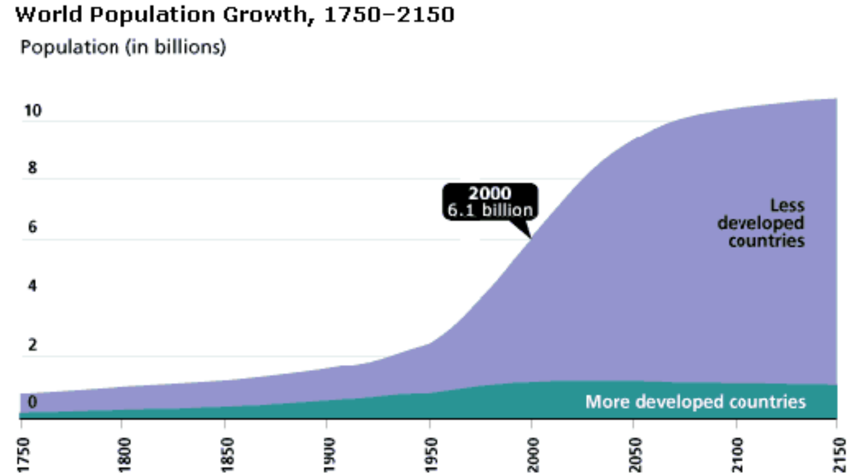




Source: United Nations, *World Population Prospects, The 1998 Revision*; and estimates by the Population Reference Bureau.

Ecology – Population Structure

Evaluation of Population Age Structure, Survivorship Patterns and Growth

Population Biology

- One of the most fascinating and fruitful areas to study in ecology is at the population level
- The **population *is*** the evolutionary unit and we do need to keep that in mind
- **How do we define a population**? Is the following statement "a group of individuals of the same species in a given area" sufficient for the definition of a population?
- What is missing?

The realm of Population Ecology

- Today we are going to deal with several aspects of population biology, but we will focus much of our attention on three -
- First, Age Structure and methods of evaluating age structure in populations
- Second, we will look at general patterns of survivorship observed in natural populations and what that means to species
- Finally will look at population growth

Before we look at our focal areas…

- Population structure has many different meanings
- Other than age structure (which will be our major focus), what **other sorts of characteristics** of populations might we consider to contribute to ***structure*** in natural systems?

Let us consider some of the others…

- Certainly **distribution in space *and* time** (spatial and temporal distributions - dispersion)
- **Genetic variability** maintained by the population
- And we will look at **movement patterns of individuals** in the population (later in the course)

Let us first consider dispersion

- With the concept of dispersion, really here we are addressing the issue of the **actual distribution of individuals in a given area**
- In general terms, we often talk about the **geographic range** of a species. What does that actually mean?
- With more precision, we can look at this in terms of **where, in space, the organisms actually exist**

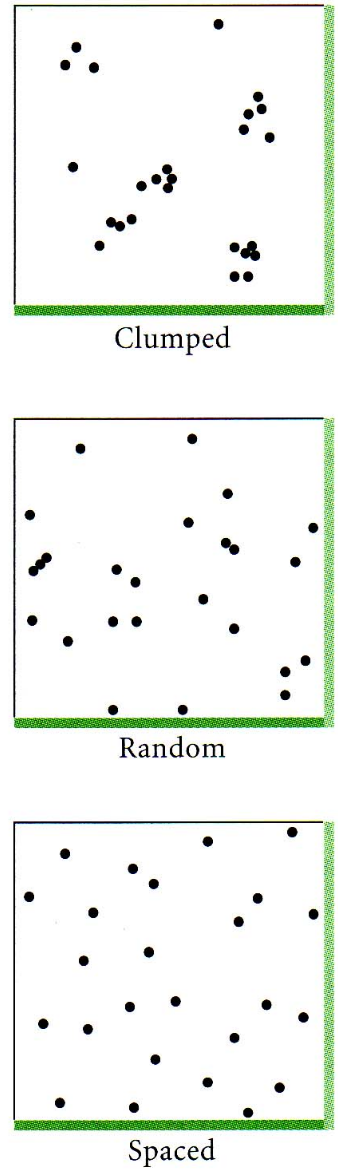


FIGURE 14-7 Diagrammatic representation of individuals in clumped, random, and evenly spaced dispersion patterns.

What might be the basis of different patterns of dispersion?

- That is, **why are the individuals of a population distributed in a particular way?**
- **Random** dispersion?
- What about **clumped** dispersion?
- Alternatively, what about the situation where the spacing is **uniform** among individuals?

From a genetic perspective…

- We can look at this from the perspective of distinctness of populations and/or movement among populations and the coincident ***gene flow***
- One very important measure of a population is the **amount of genetic variability** maintained in a natural population (this is of primary importance for a population)
- This measure is an evaluation of the **amount of variation present in the population**

Methods to Evaluate Variability

- We talked about variation and its sources when we looked at evolution. **The phenotypic variability displayed by individuals is a result of the interaction between genetic features and environmental influences**
- However, **to accurately evaluate variation in the gene pool**, we need to employ methods that look at genetic features – e.g.?

When evaluating any feature of a population – **is it a *closed* entity**?

- That is, for many analyses, we want to evaluate that population, or at least the group of individuals that we **think** is a population
- Many times the terms **source and sink populations** are used to describe such situations. Here, there is essentially one-way movement of individuals (*and genes*) from the source population or populations to other subpopulation(s)
- This obviously can create difficulties in the analysis of a population

Why is assessment of variation important information?

- These analyses give us a feel for **population boundaries**
- This can **identify patterns in geographic variation**, subpopulations, and even contribute to our understanding of historical events influencing this population – **How?**

Another Measure is Estimation of Density in a Geographic Area

- In looking at the dispersion of individuals in a population, it is important to be able to **evaluate the density of organisms** in that habitat. Why might this be of value?
- Generally, **a complete census is not practical or even possible**, rather we use estimating tools
- What is the **most common estimating technique?**

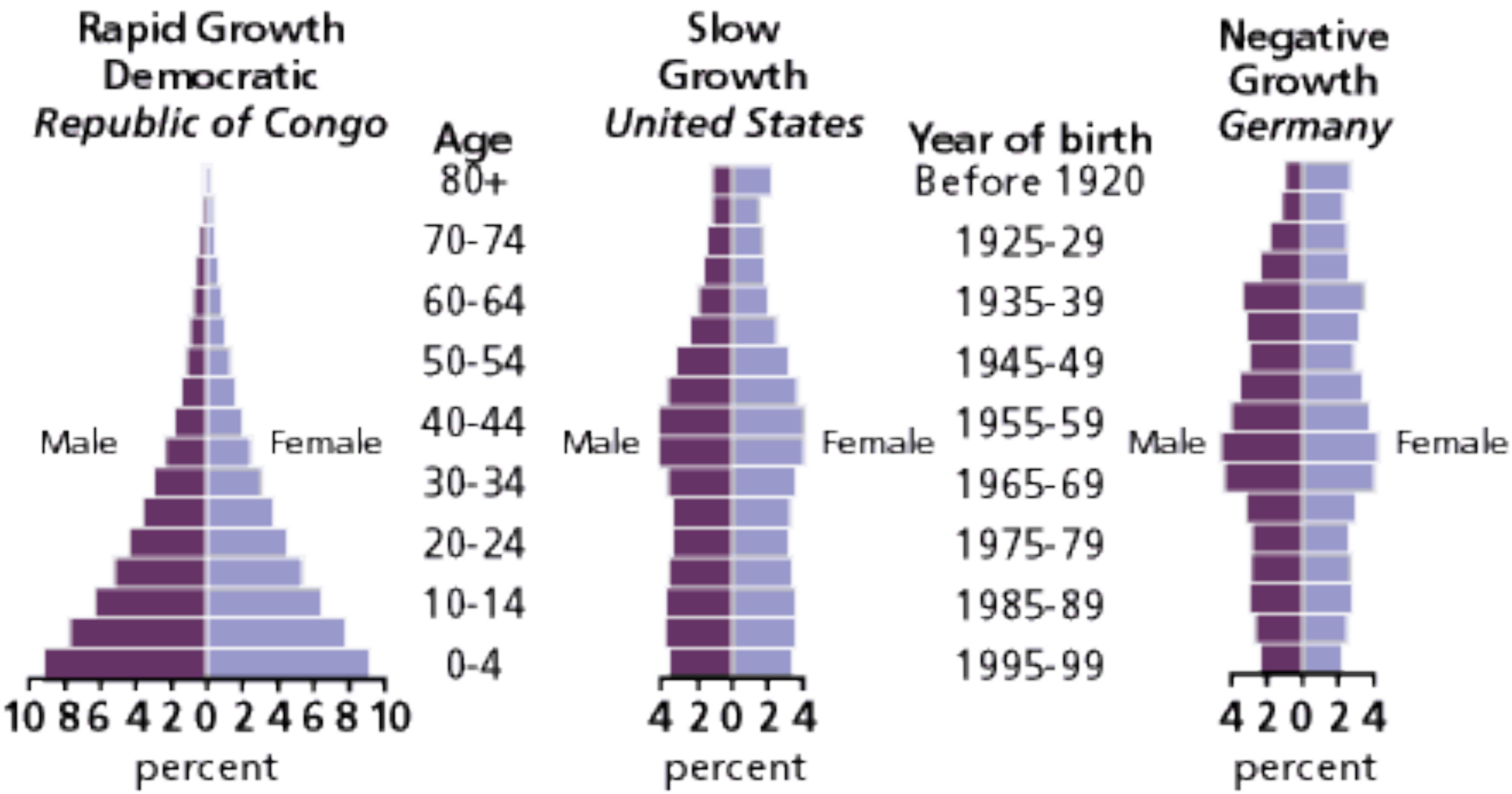
Mark – Recapture Methods

- This is a very **effective and common technique** used to estimate population size and often times a realistic measure of a ***closed* system**
- The **calculation is simple:**
  $x/n = M/N$ (we will not be using this formula)
- This procedure gives us a quick **measure of the population size** in that area

Age Structure in Populations

- Basically, this is a **function of the age or age class distribution in a population**
- There are **several ways** to evaluate this:
  - **Follow a cohort of individuals through time** and obtain direct measurement of number of individuals at each age class (this is ideal)
  - Look at the **entire population** and measure the percentage of individuals in each age class
  - Look at the **age at which individuals die**

These data can be used to construct Age Class Distributions



What do the three types mean?

- The previous figure displays **human sample populations derived from the horizontal method of analysis**
- **Can we say anything** about the stability of the populations? How are these data most useful?
- As an example, what if we measured the age structure distribution of a population of fish. **What can we say about the population stability of a single population?**

Other uses of this information

- Detailed **analysis of life history characteristics**, such as the age at which individuals die, can be used to construct life tables
- Let us look at these features from a study of a population of Darwin's ground finches
- We can obtain this type of data only by **following a cohort through time**. (But, as you can imagine, this is not simple and often involves estimation of several parameters to reach our life table estimates.)

What are the features we want to measure?

TABLE 14-4 Summary of life table variables

l_x	Survival of newborn individuals to age x
b_x	Fecundity at age x (female offspring produced per breeding season or age interval)
m_x	Proportion of individuals of age x dying by age $x + 1$
s_x	Proportion of individuals of age x surviving to age $x + 1$
e_x	Expectation of further life of individuals of age x
k_x	$-\log_e s_x$, the exponential mortality rate between age x and $x + 1$

TABLE 14-5 Life table of the 1978 cohort of Darwin's ground finch *Geospiza scandens* on Isla Daphne Major, Galápagos

Age (x)*	Number alive	Survivorship (l_x)	Mortality rate (m_x)	Survival rate (s_x)	Expectation of life (e_x)	Exponential mortality (k_x)
0	(210)†	1.000	0.566	0.434	2.84	0.835
1	91	0.434	0.143	0.855	4.91	0.157
2	78	0.371	0.102	0.898	4.64	0.107
3	70	0.333	0.072	0.928	4.11	0.075
4	65	0.309	0.045	0.955	3.39	0.046
5	62	0.295	0.322	0.678	2.53	0.389
6	42	0.200	0.455	0.545	2.50	0.607
7	23	0.109	0.349	0.651	3.11	0.429
8	15	0.071	0.056	0.944	3.50	0.057
9	14	0.067	0.224	0.776	2.71	0.266
10	11	0.052	0.077	0.923	2.32	0.070
11	10	0.048	0.604	0.396	1.50	0.926
12	4	0.019	0.263	0.737	2.00	0.305
13	3	0.014	(0.004)	0.714	(1.50)	0.337
>14	(3)	(0.000)	(1.000)	0.000	. . .	. . .

*Age in years

†Estimated

(After Grant and Grant 1992.)

Graphically, we can just look at survivorship in various species

- From natural populations, we can identify **three general trends**
- These are expressed as a **plot of the log of the number of individuals surviving as a function of the percent of normal life span of an individual**

The three general patterns are…

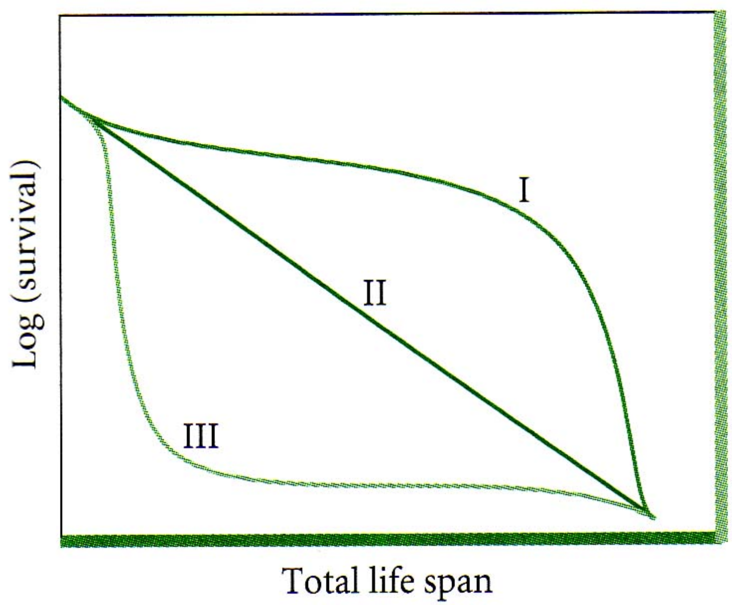


FIGURE 14-17 Depiction of three idealized survivorship curves. Populations with a type I survivorship curve have more mortality in the older age classes, whereas a considerable amount of mortality occurs among the youngest individuals in populations with type III curves.

Patterns indicate many features – much more than just survivorship

- Conceptually, **what does each curve tell us?**
- We start to see **patterns emerge**, particularly with regard to strategies of reproduction
- We find suites of coincidental features. We can divide the organisms into either ***r*** strategists or ***K*** strategists
- We will develop this in detail when we look at population growth patterns

Break time!

The various population measures

- These features identified so far all contain valuable information regarding the population under study
- We still have a very important component of population biology to address – **growth**
- We will look at **population growth models and make some generalizations about organisms and their reproductive strategies**

TABLE 14-4 Summary of life table variables

l_x	Survival of newborn individuals to age x
b_x	Fecundity at age x (female offspring produced per breeding season or age interval)
m_x	Proportion of individuals of age x dying by age $x + 1$
s_x	Proportion of individuals of age x surviving to age $x + 1$
e_x	Expectation of further life of individuals of age x
k_x	$-\log_e s_x$, the exponential mortality rate between age x and $x + 1$

We can evaluate reproductive rates

- Simplistically, we can evaluate the **rate of increase** as ***B – D*** (on a population level)
- But population level measures are often difficult to determine. Alternatively, with our data we can predict the **average output of an individual and the average death rate of an individual** (from our $\boldsymbol{b_x}$ and our $\boldsymbol{l_x}$). Simply put, the individual birth rate – the individual death rate ***(b – d)*** or ***r*** (it is not quite that simple, but we will treat the details in a few)

Mathematically, what is ***r***?

- ***r*** is a very important variable for our consideration as much of population growth modeling and theory is based upon this value
- By definition, ***r*** **is the intrinsic rate of increase or the rate of increase in a population under ideal conditions with a stable age distribution – simply put, the birth rate minus the death rate**

Stable Age Distributions

- If our population exhibits a **stable age-class distribution, mathematically this means that each age class is changing (increasing) at the same (exponential) rate** – this can be proven mathematically, but it also makes sense
- Now, what goes into that **estimation of *r*?**
- Well, again it is **greatly dependent on the fecundity and survivorship**

Estimation of ***r*** from other data

- This estimation is based upon the **probable output of all age classes** to arrive at a particular estimate. It is, in effect, an estimation of rate from the data that will give us a population level characteristic or feature
- We can then use this information to calculate **population size over time**, **e.g.** $\mathbf{N_t = N_0e^{rt}}$ (continuous reproductive output)

Look at this formula more closely

- The predictions here are **the result of the capacity of the individuals to reproduce – *without other restrictions.*** This formula describes exponential growth in a population (continuous addition of offspring) or geometric growth (for seasonally defined addition of offspring on a periodic basis)
- Note, **for geometric growth, $\lambda = e^r$** (discrete addition of new members to the population)

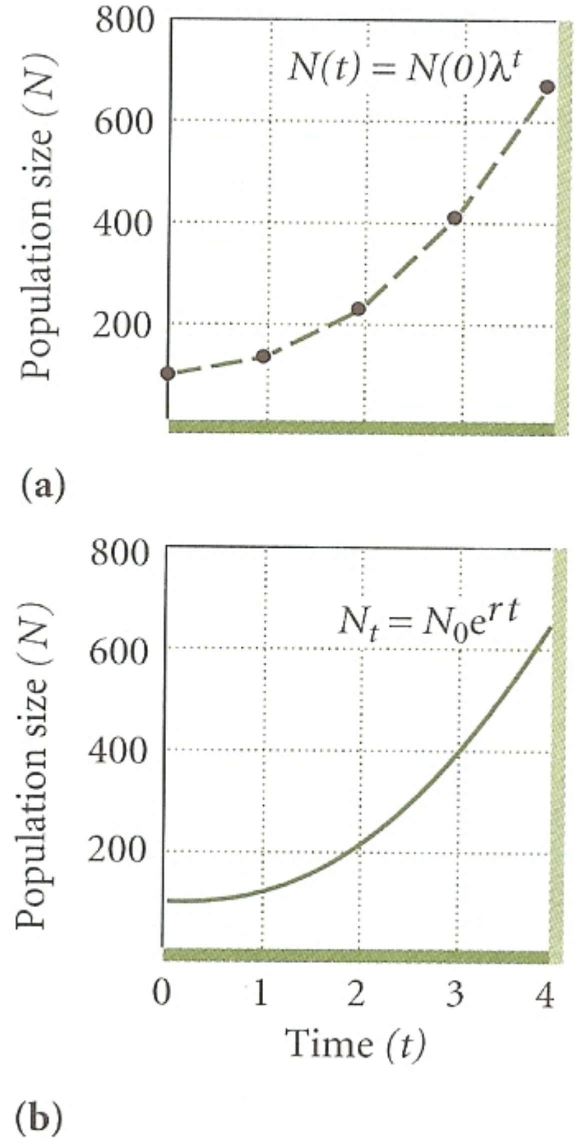
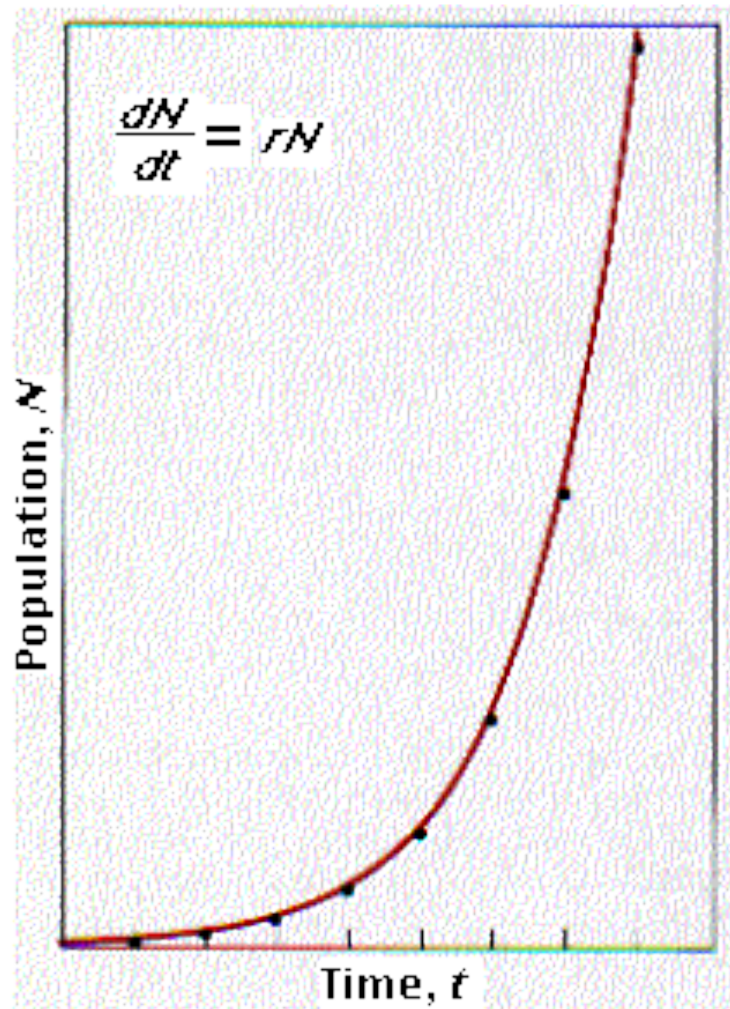


FIGURE 15-4 Increase in the number of individuals in populations undergoing (a) geometric growth and (b) exponential growth at equivalent rates (λ = 1.6, r = 0.47).

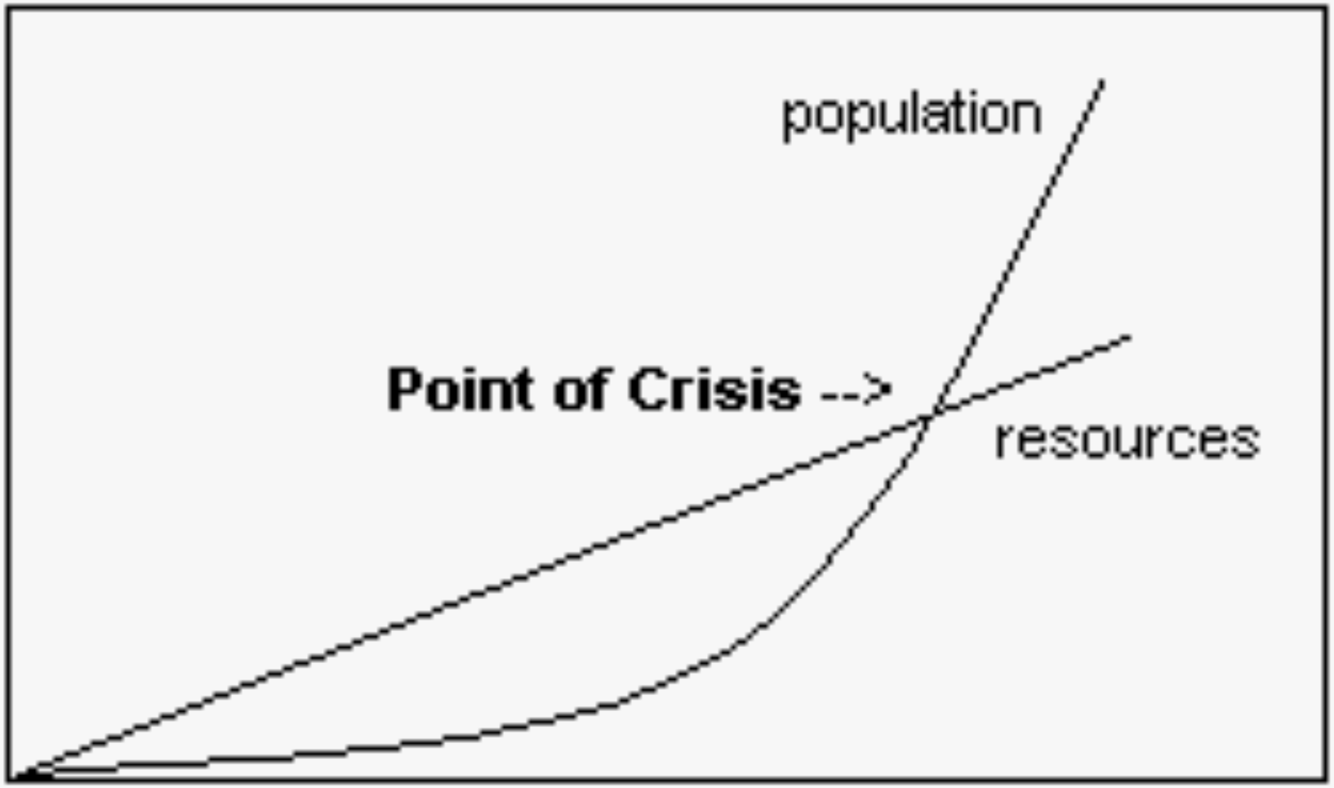
Exponential growth in a population

The formula that represents the slope of this line, **dN/dt=rN, is the instantaneous rate of increase** for this population. That is, this formula tells us the rate of increase for the population at any population size for groups exhibiting exponential growth.



Now, let us do a reality check

- **What does exponential growth suggest**? Is that the situation we see under most natural conditions?
- One of the primary contributions to the thinking of Charles Darwin was an essay written by Thomas **Malthus** regarding population growth
- Although Malthus predicted an outcome for humans, it is applicable to all organisms under consideration – **the struggle for resources**

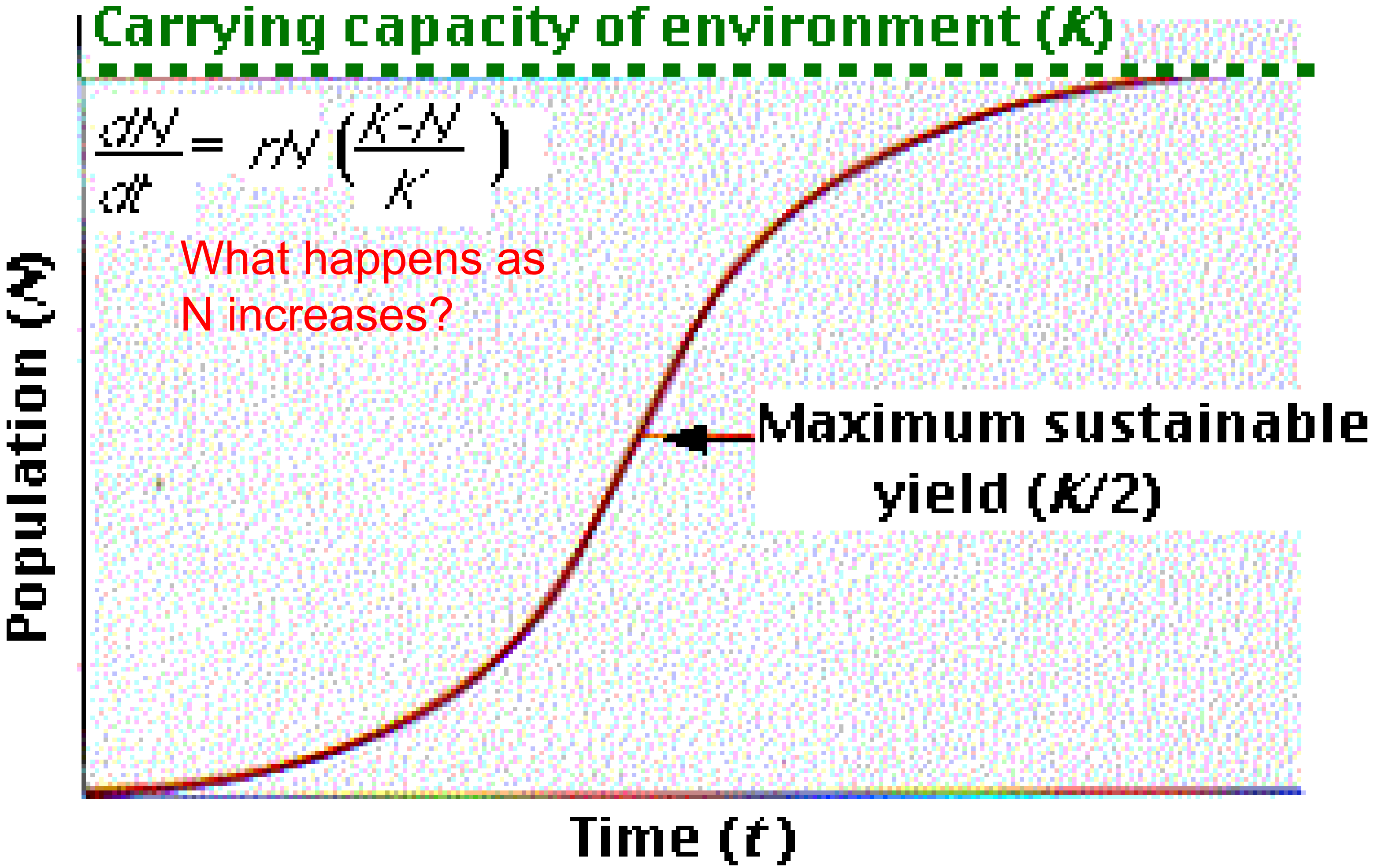


Malthus' Basic Theory

How can we apply this?

- Very early in the study of population ecology, the **recognition of limited resources** was considered when modeling population growth
- A term was devised, called the **environmental resistance to growth**
- Mathematically, the term is **(1 – N/K)**
- Look at what this means for the ***rate***

Graphically, this is logistic growth

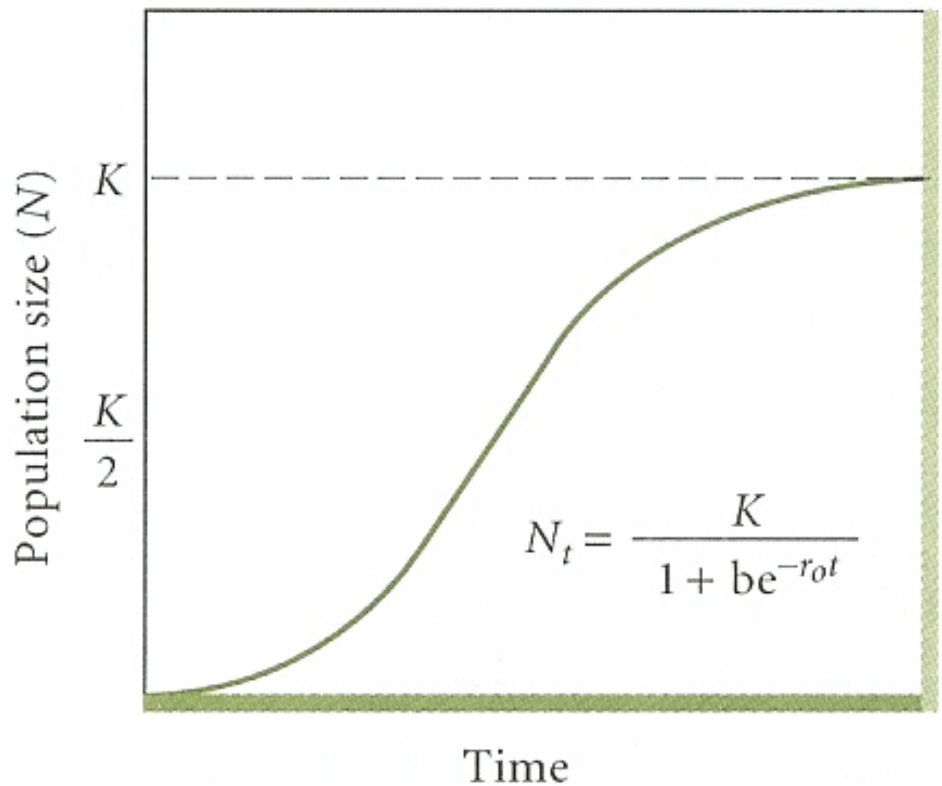


Look at the shape of that curve

- This curve is picture-perfect. A well-behaved population of organisms
- **What directly influences the shape of this curve,** and more importantly, the rate associated with the logistic population growth model?
- What happens when we **change those parameters**?

Predictions of Logistic Growth

- The reality of nature dictates that organisms will not exhibit exponential or geometric growth for extended periods of time
- That is, $dN/dt=0$ at $N=K$ (remember the environmental resistance to growth)
- This is Logistic Population Growth



We can calculate the population size at some point in time *t* and the quantity *b* is basically the starting population size for the specific situation.

FIGURE 16-4 According to the logistic growth equation, increase in numbers over time follows an S-shaped curve that is symmetrical about the inflection point ($K/2$). That is, accelerating and decelerating phases of population growth have the same shape.

What happens to the rate?

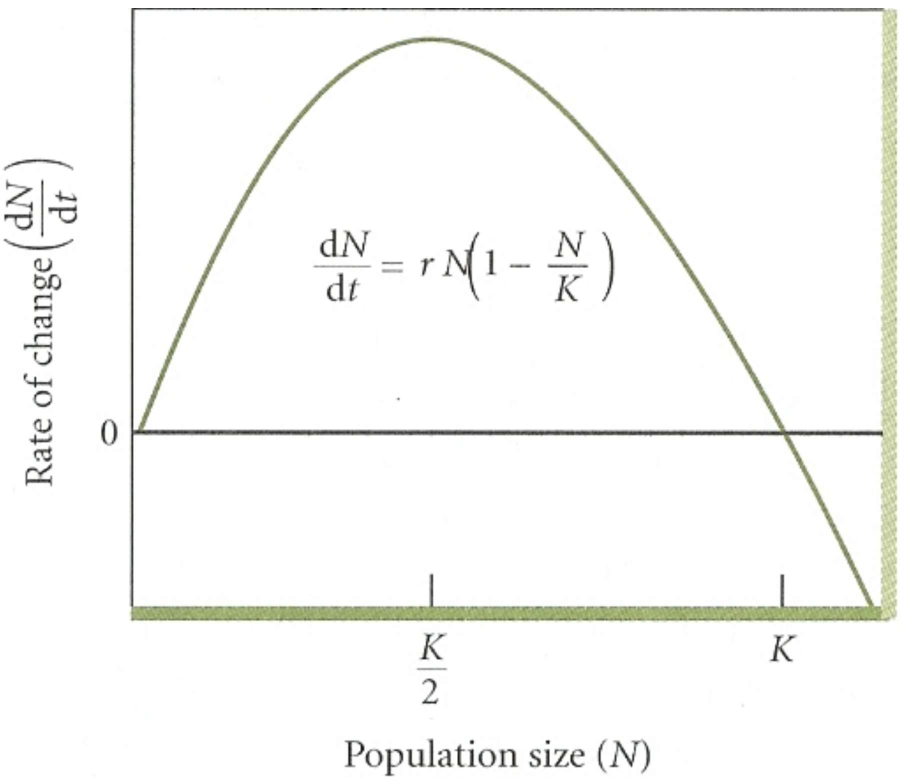
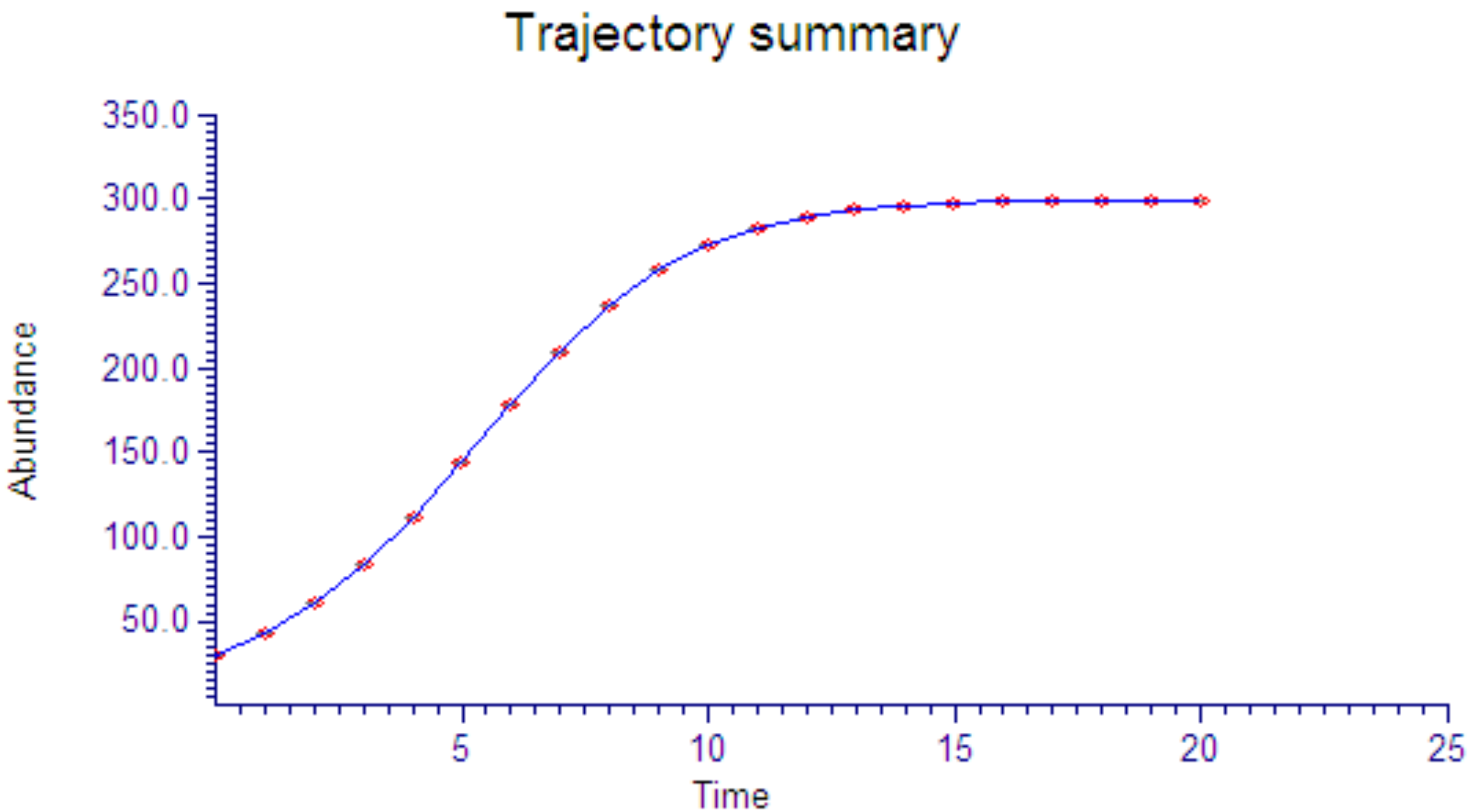


FIGURE 16-3 The logistic curve $dN/dt = rN(1 - N/K)$, where r is the population growth rate, N is the population size, and K is the carrying capacity. The population growth rate, dN/dt, is 0 when $N = 0$ or when $N = K$. The rate is at its maximum when $N = K/2$.

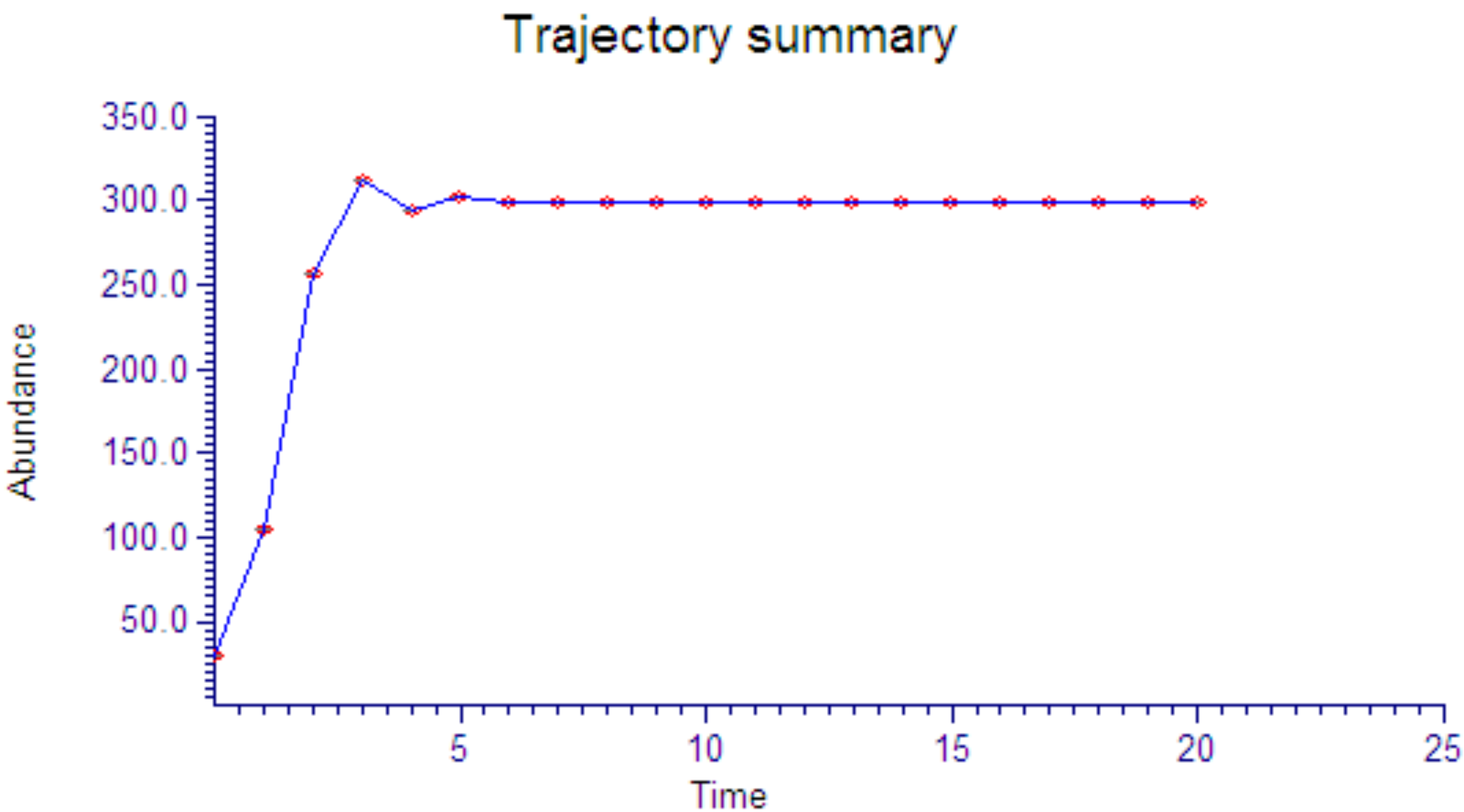
These curves are predictions

- This curve is a prediction of a “well-behaved population” of organisms
- The most important factor influencing this curve is the value of ***r*** (the difference between the birth rate and death rate)
- What happens when we change those parameters?

When *r* is small, ~1.5

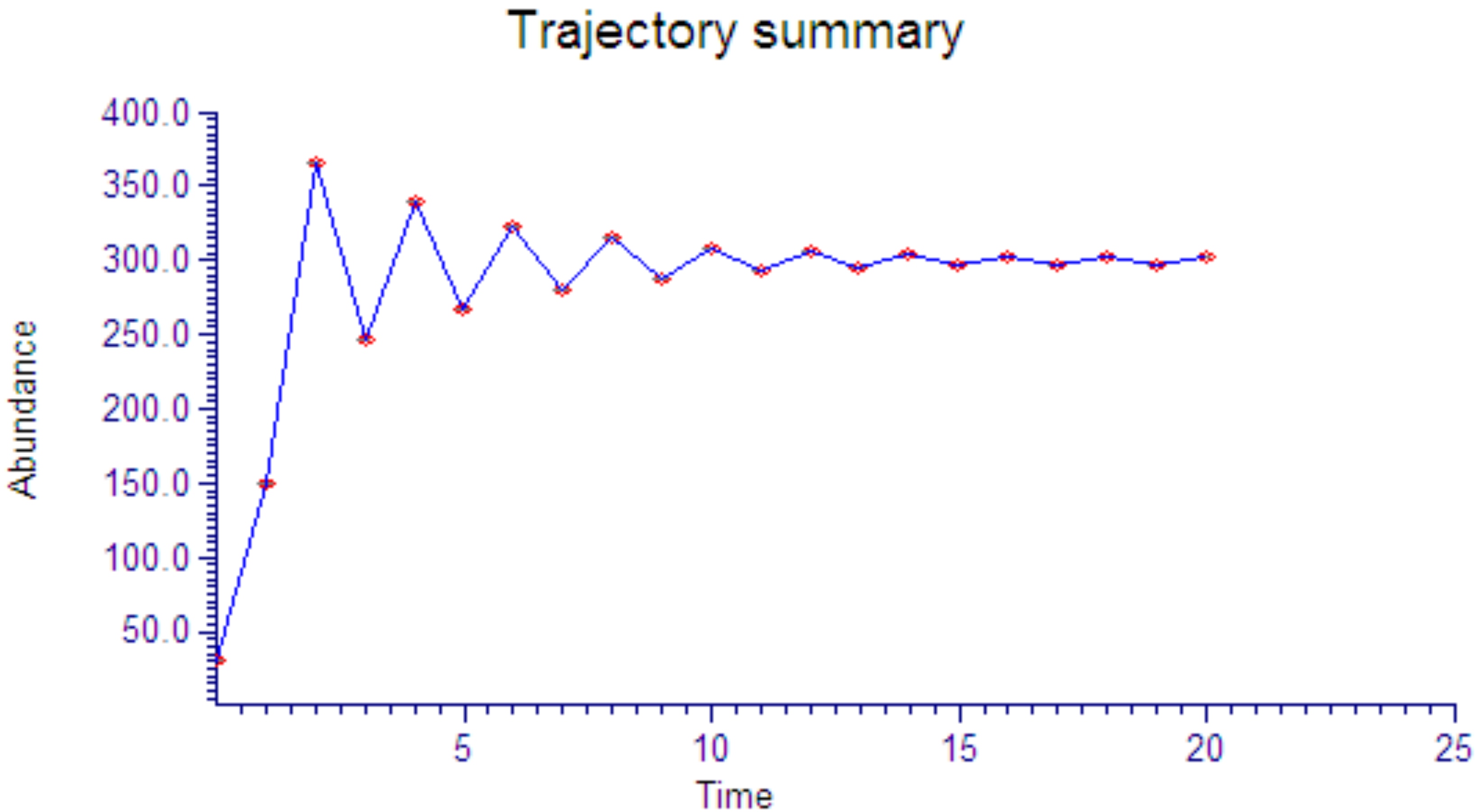


$r = 4.0$



Trajectory summary
Abundance
350.0
300.0
250.0
200.0
150.0
100.0
50.0
5
10
15
20
25
Time

r = 6.0



Trajectory summary
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
Abundance
5
10
15
20
25
Time

When *r* gets very large, ~ 10