MARINE CONSERVATION SCIENCE AND POLICY SERVICE LEARNING PROGRAM

Population sampling refers to the process through which a group of representative individuals is selected from a population for the purpose of statistical analysis. Performing population sampling correctly is extremely important, as errors can lead to invalid or misleading data. There are a number of techniques used in population sampling to ensure that the individuals can be used to generate data which can in turn be used to make generalizations about a larger population.

MODULE 3: OCEAN CONNECTIONS

SECTION 4: POPULATION SAMPLINGS

SUNSHINE STATE STANDARDS

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SC.912.L.17.8,

OBJECTIVES
- Understand the concept of population
- Learn about the factors that affect a population in an area
- Use proper scientific method and sampling techniques.
- Explain the methods used to determine the population in a particular area.
- Use math to calculate percent error.
- Explain additional population sampling methods.
- Understand the concept of population dynamic
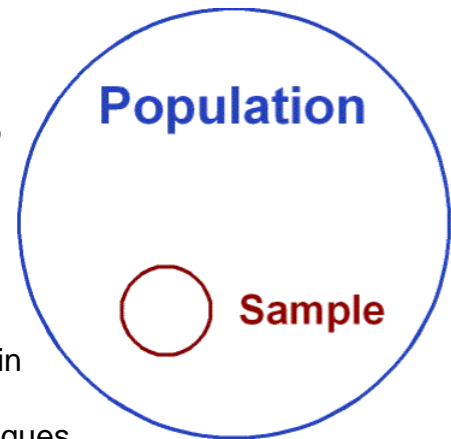
VOCABULARY

Birth rate- The ratio between births and individuals in a specified population at a particular time.

Carrying capacity- The maximum population size that can be regularly sustained by an environment; the point where the population size levels off in the logistic growth model.

Competitive exclusion- Competition between species that is so intense that one species completely eliminates the second species from the area.

Competitive release- Occurs when one of two competing species is removed from an area, thereby releasing the remaining species from one of the factors that limited its population size.

Competition- One of the biological interactions that can limit population growth; occurs when two species vie with each other for the same resource.

Commensalism- A symbiotic relationship in which one species benefits and the other is not affected.

Death rate- The ratio between deaths and individuals in a specified population at a particular time.

Exponential rate - An extremely rapid increase, e.g., in the rate of population growth.

Extinction- The elimination of all individuals in a group, both by natural (dinosaurs, trilobites) and human-induced (dodo, passenger pigeon).

Genetic drift- Random changes in the frequency of alleles from generation to generation; especially in small populations, can lead to the elimination of a particular allele by chance alone.

Habitat disruption- A disturbance of the physical environment in which a population lives.

Law of the minimum- Holds that population growth is limited by the resource in shortest supply.

Life history- The age at sexual maturity, age at death, and age at other events in an individual's lifetime that influence reproductive traits.

Logistic growth model- A model of population growth in which the population initially grows at an exponential rate until it is limited by some factor; then, the population enters a slower growth phase and eventually stabilizes.

Minimum viable population (MVP)- The smallest population size that can avoid extinction due to breeding problems or random environmental fluctuations.

Mutualism- A form of symbiosis in which both species benefit. A type of symbiosis where both organisms benefit. The classic example is lichens, which is a symbiosis between an alga and a fungus. The alga provides food and the fungus provides water and nutrients.

Niche- The biological role played by a species.

Niche overlap- The extent to which two species require similar resources; species the strength of the competition between the two species.

Parasitism- A form of symbiosis in which the population of one species beneÞts at the expense of the population of another species; similar to predation, but differs in that parasites act more slowly than predators and do not always kill the host. A type of symbiosis in which one organism benefits at the expense of the other, for example the influenza virus is a parasite on its human host. Viruses, are obligate intracellular parasites.

Population- A group of individuals of the same species living in the same area at the same time and sharing a common gene pool. A group of potentially interbreeding organisms in a geographic area.

BACKGROUND

Population Growth

A population is a group of individuals of the same species living in the same geographic area. The study of factors that affect growth, stability, and decline of populations is population dynamics. All populations undergo three distinct phases of their life cycle:

1. growth
2. stability
3. decline

Population growth occurs when available resources exceed the number of individuals able to exploit them.

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"Come on, you can always fit one more."

Reproduction is rapid, and death rates are low, producing a net increase in the population size.

Population stability is often preceded by a "crash" since the growing population eventually outstrips its available resources. Stability is usually the longest phase of a population's life cycle.

Decline is the decrease in the number of individuals in a population, and eventually leads to population extinction.

Factors Influencing Population Growth

Nearly all populations will tend to grow exponentially as long as there are resources available. Most populations have the potential to expand at an exponential rate, since reproduction is generally a multiplicative process. Two of the most basic factors that affect the rate of population growth are the birth rate, and the death rate. The intrinsic rate of increase is the birth rate minus the death rate.
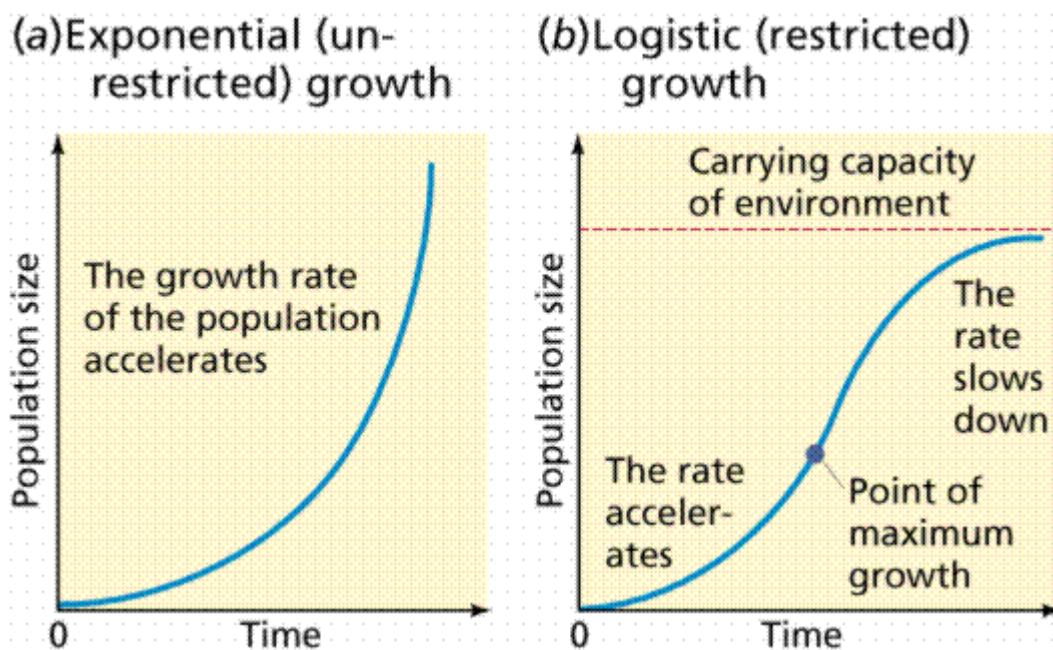

Two modes of population growth. The Exponential curve (also known as a J-curve) occurs when there is no limit to population size. The Logistic curve (also known as an S-curve) shows the effect of a limiting factor (in this case the carrying capacity of the environment). Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission.

## Population Growth Potential Is Related to Life History

The age within its individual life cycle at which an organism reproduces affects the rate of population increase. Life history refers to the age of sexual maturity, age of death,

and other events in that individual's lifetime that influence reproductive traits. Some organisms grow fast, reproduce quickly, and have abundant offspring each reproductive cycle. Other organisms grow slowly, reproduce at a late age, and have few offspring per cycle. Most organisms are intermediate to these two extremes.
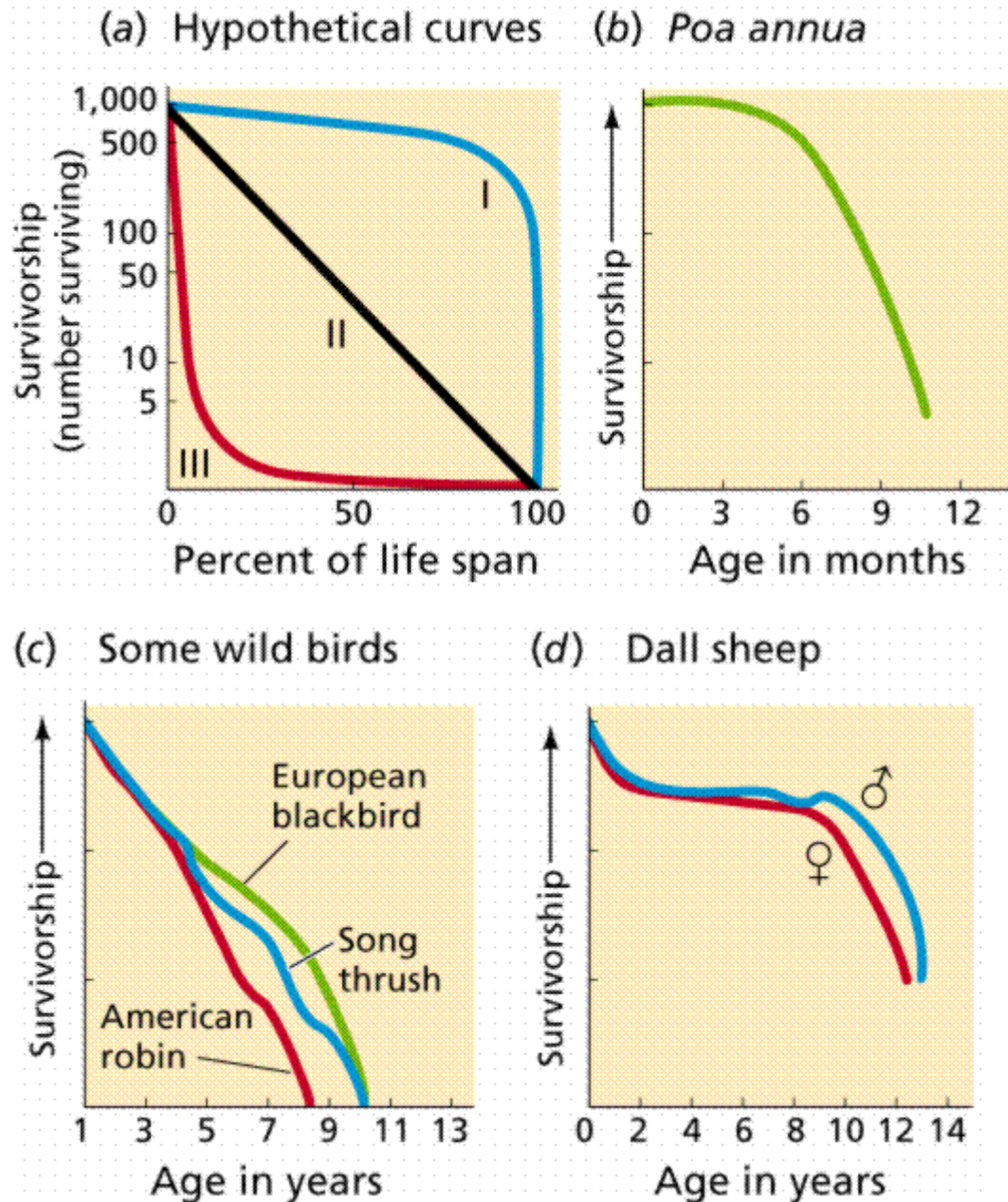

Population curves. a) three hypothetical populations (labelled I, II, and III); b, c, and d) three real populations. Note that the real curves approximate one of the three hypotheticals. Images from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission.

Age structure refers to the relative proportion of individuals in each age group of a population. Populations with more individuals aged at or before reproductive age have a pyramid-shaped age structure graph, and can expand rapidly as the young mature and breed. Stable populations have relatively the same numbers in each of the age classes.
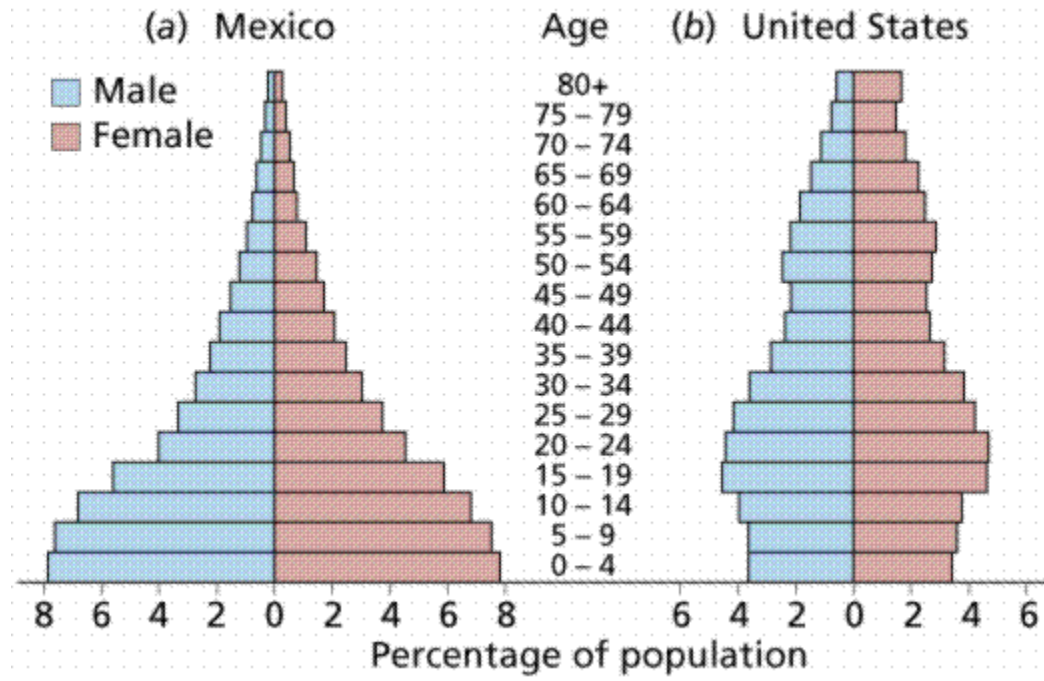

Comparison of the population age structuire in the United States and Mexico. Note the deographic bulge in the Mexican population. The effects of this buldge will be felt for generations. Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission.
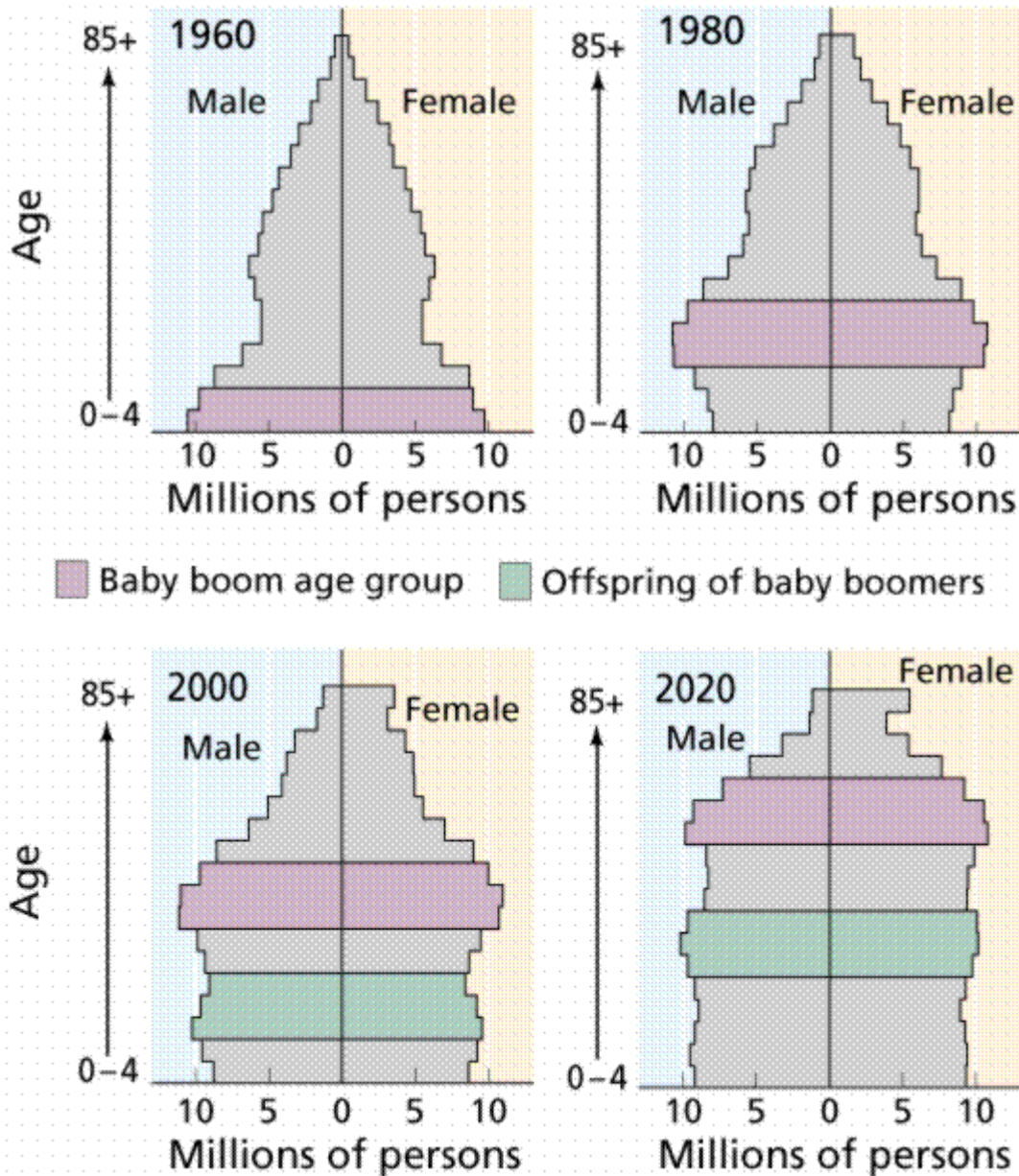
The Baby Boomers and Gen X. As the population bulge, the baby Boomers born after World War II, aged and began to have children of their own this created a secondary bulge termed Generation X. What happens when the Generation X members begin to have their own children? Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission.

Human populations are in a growth phase. Since evolving about 200,000 years ago, our species has proliferated and spread over the Earth. Beginning in 1650, the slow population increases of our species exponentially increased. New technologies for hunting and farming have enabled this expansion. It took 1800 years to reach a total population of 1 billion, but only 130 years to reach 2 billion, and a mere 45 years to reach 4 billion.

Despite technological advances, factors influencing population growth will eventually limit expansion of human population. These will involve limitation of physical and biological resources as world population increased to over six billion in 1999. The 1987 population was estimated at a puny 5 billion.
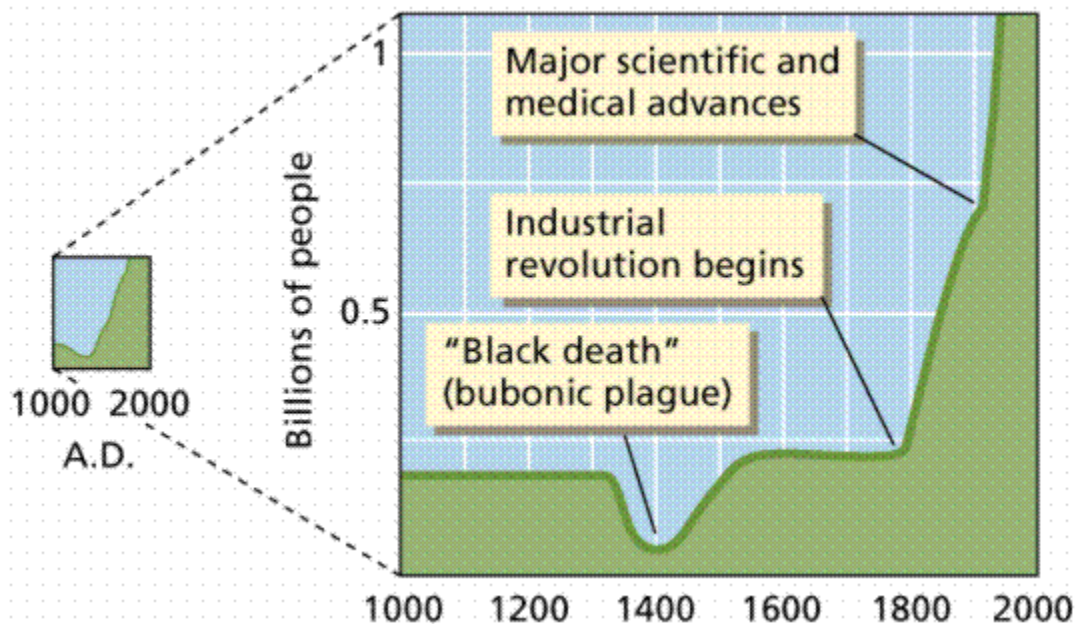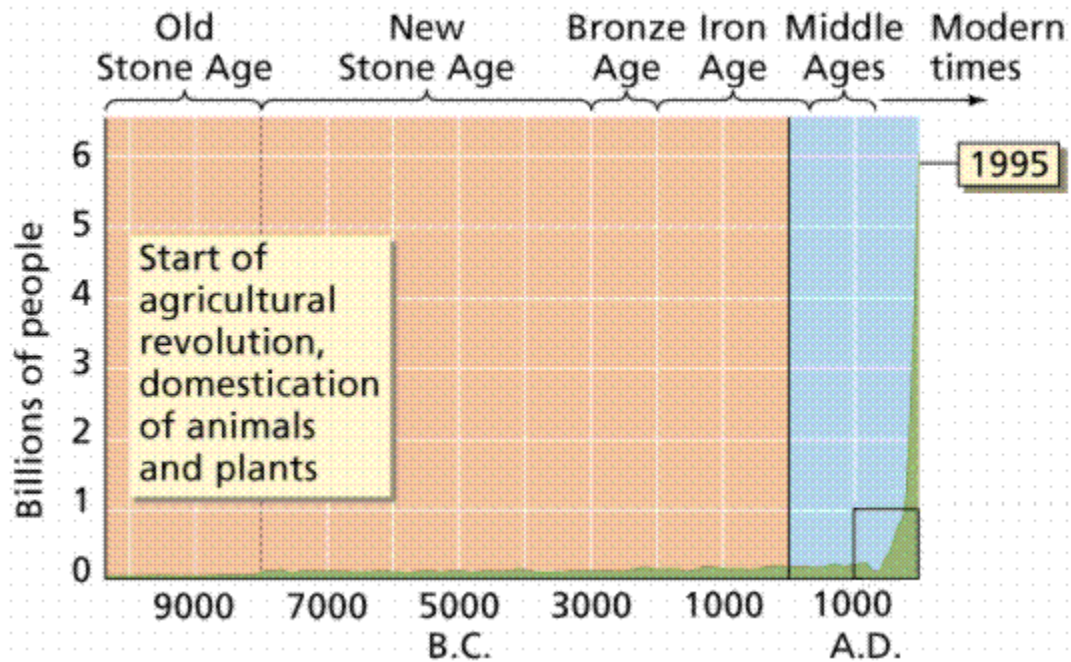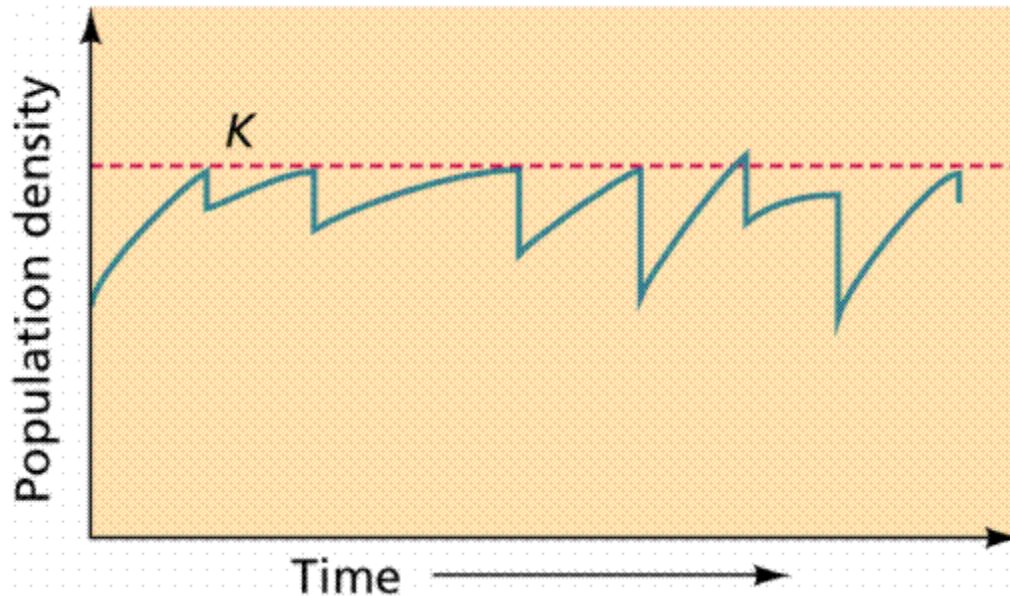

Human population growth over the past 10,000 years. Note the effects of worldwide disease (the Black death) and technological advances on the populatiuon size. Images from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission.

Populations Transition between Growth and Stability

Limits on population growth can include food supply, space, and complex interactions with other physical and biological factors (including other species). After an initial period of exponential growth, a population will encounter a limiting factor that will cause the exponential growth to stop. The population enters a slower growth phase and may eventually stabilize at a fairly constant population size within some range of fluctuation. This model fits the logistic growth model. The carrying capacity is the point where population size levels off.

Relationship between carrying capacity (K) and the population density over time. Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission.

Several Basic Controls Govern Population Size

The environment is the ultimate cause of population stabilization. Two categories of factors are commonly used: physical environment and biological environment. Three subdivisions of the biological environment are competition, predation, and symbiosis.

Physical environment factors include food, shelter, water supply, space availability, and (for plants) soil and light. One of these factors may severely limit population size, even if the others are not as constrained. The Law of the Minimum states that population growth is limited by the resource in the shortest supply.

The biological role played by a species in the environment is called a niche. Organisms/populations in competition have a niche overlap of a scarce resource for which they compete. Competitive exclusion occurs between two species when competition is so intense that one species completely eliminates the second species from an area. In nature this is rather rare. While owls and foxes may compete for a common food source, there are alternate sources of food available. Niche overlap is said to be minimal.
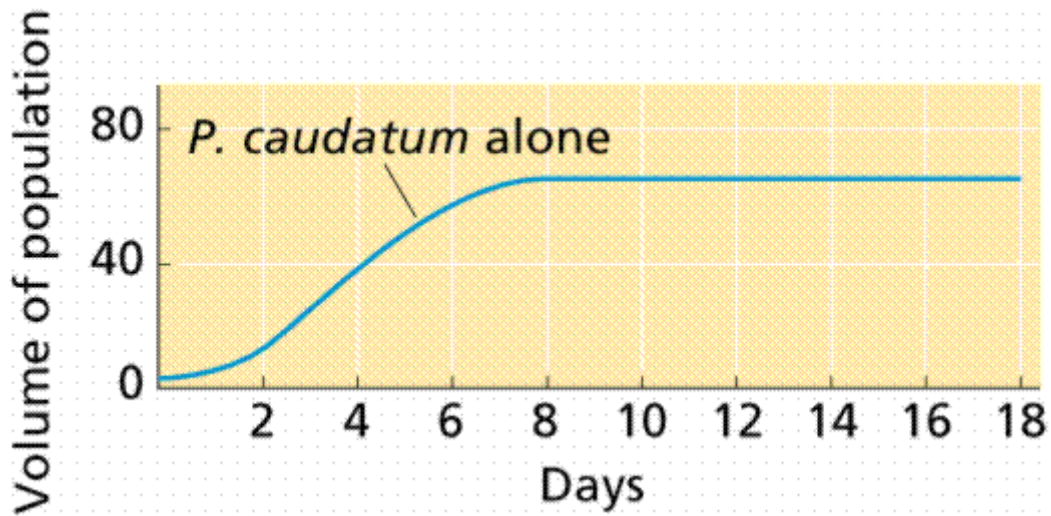
Paramecium aurelia has a population nearly twice as large when it does not have to share its food source with a competing species. Competitive release occurs when the competing species is no longer present and its constraint on the winner's population size is removed
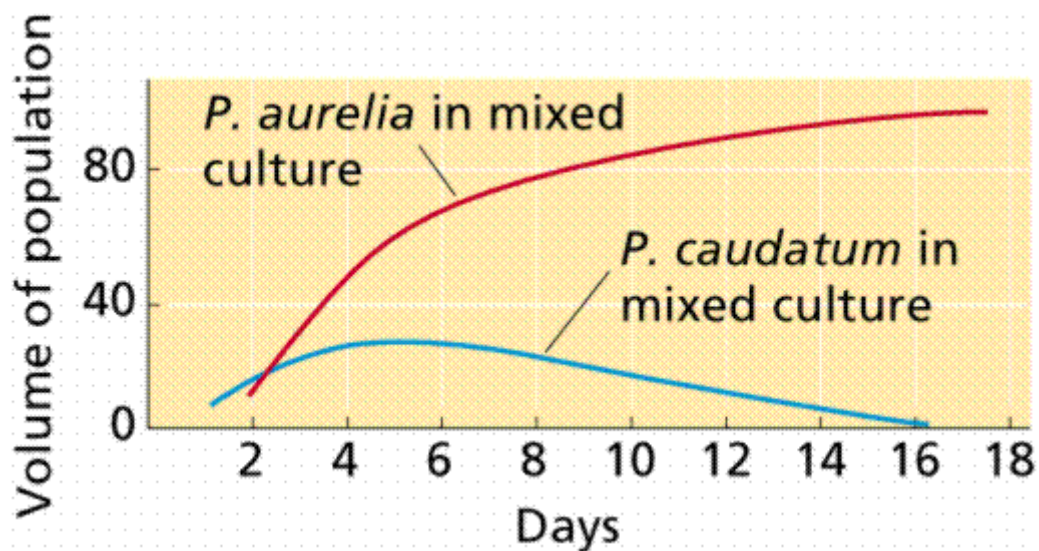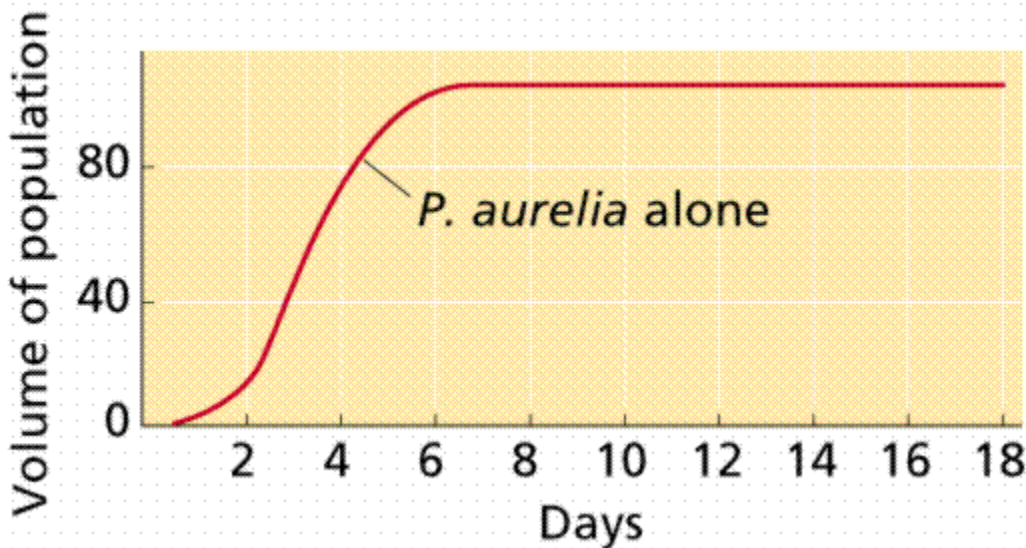
Graphs showing competition between two species of *Paramecium*. Since each population alone prospers (yop two

graphs), when they are in a competition situation one species will win, the other will lose (bottom graph). Images from Purves et al., <u>Life: The Science of Biology</u>, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission..

Predators kill and consume other organisms. Carnivores prey on animals, herbivores consume plants. Predators usually limit the prey population, although in extreme cases they can drive the prey to extinction. There are three major reasons why predators rarely kill and eat all the prey:

1. Prey species often evolve protective mechanisms such as camouflage, poisons, spines, or large size to deter predation.
2. Prey species often have refuges where the predators cannot reach them.
3. Often the predator will switch its prey as the prey species becomes lower in abundance: prey switching.
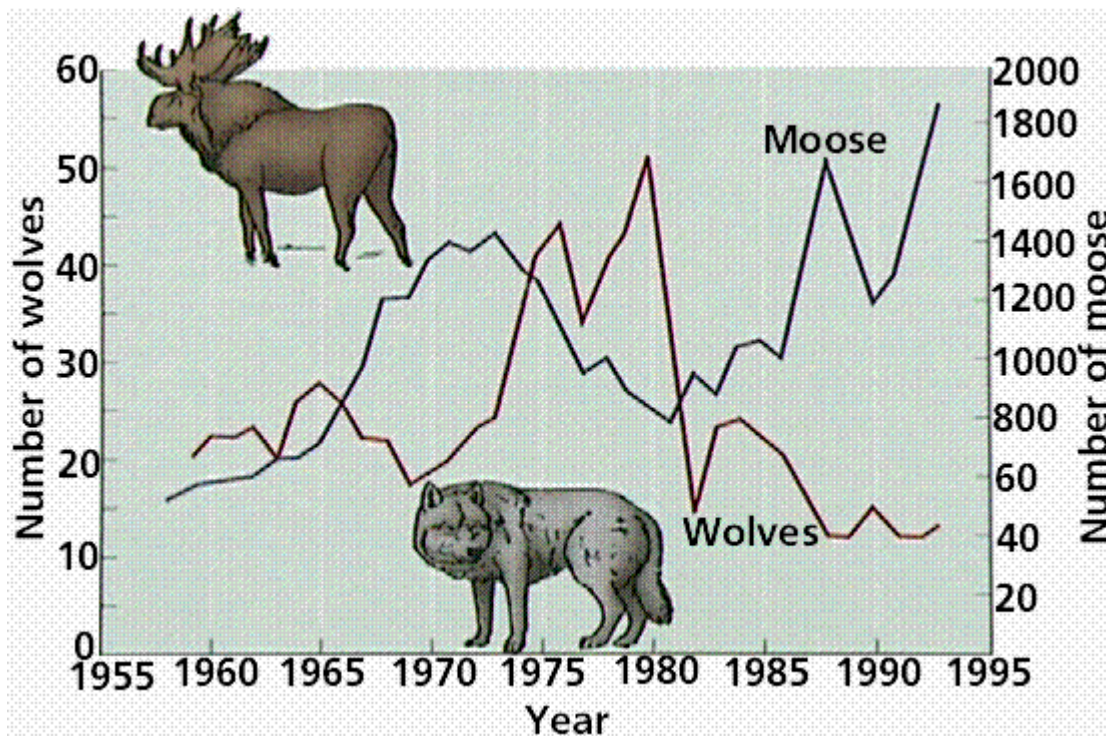
Fluctuations in predator (wolf) and prey (moose) populations over a 40-year span. Note the effects of declines in the wolf population in the late 1960s and again in the early 1980s on the moose population. Image from Purves et al., <u>Life: The Science of Biology</u>, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com), used with permission.

Symbiosis has come to include all species interactions besides predation and competition. Mutualism is a symbiosis where both parties benefit, for example algae (zooxanthellae) inside reef-building coral. Parasitism is a symbiosis where one species benefits while harming the other. Parasites act more slowly than predators and often do not kill their host. Commensalism is a symbiosis where one species benefits and the other is neither harmed nor gains a benefit: Spanish moss on trees, barnacles on crab

shells. Amensalism is a symbiosis where members of one population inhibit the growth of another while being unaffected themselves.

The Real World Has a Complex Interaction of Population Controls

Natural populations are not governed by a single control, but rather have the combined effects of many controls simultaneously playing roles in determining population size. If two beetle species interact in the laboratory, one result occurs; if a third species is introduced, a different outcome develops. The latter situation is more like nature, and changes in one population may have a domino effect on others.

Which factors, if either, is more important in controlling population growth: physical or biological? Physical factors may play a dominant role, and are called density independent regulation, since population density is not a factor The other extreme has biological factors dominant, and is referred to as density dependent regulation, since population density is a factor. It seems likely that one or the other extreme may dominate in some environments, with most environments having a combination control.

Population Decline and Extinction

Extinction is the elimination of all individuals in a group. Local extinction is the loss of all individuals in a population. Species extinction occurs when all members of a species and its component populations go extinct. Scientists estimate that 99% of all species that ever existed are now extinct. The ultimate cause of decline and extinction is environmental change. Changes in one of the physical factors of the environment may cause the decline and extinction; likewise the fossil record indicates that some extinctions are caused by migration of a competitor.

Dramatic declines in human population happen periodically in response to an infectious disease. Bubonic plague infections killed half of Europe's population between 1346 and 1350, later plagues until 1700 killed one quarter of the European populace. Smallpox and other diseases decimated indigenous populations in North and South America.

Human Impact

Human populations have continued to increase, due to use of technology that has disrupted natural populations. Destabilization of populations leads to possible outcomes:

- population growth as previous limits are removed
- population decline as new limits are imposed

Agriculture and animal domestication are examples of population increase of favored organisms. In England alone more than 300,000 cats are put to sleep per year, yet

before their domestication, the wild cat ancestors were rare and probably occupied only a small area in the Middle East.

Pollution

Pollutants generally are (unplanned?) releases of substances into the air and water. Many lakes often have nitrogen and phosphorous as limiting nutrients for aquatic and terrestrial plants. Runoff from agricultural fertilizers increases these nutrients, leading to runaway plant growth, or eutrophication. Increased plant populations eventually lead to increased bacterial populations that reduce oxygen levels in the water, causing fish and other organisms to suffocate.

Pesticides and Competition

Removal of a competing species can cause the ecological release of a population explosion in that species competitor. Pesticides sprayed on wheat fields often result in a secondary pest outbreak as more-tolerant-to-pesticide species expand once less tolerant competitors are removed.

Removal of Predators

Predator release is common where humans hunt, trap, or otherwise reduce predator populations, allowing the prey population to increase. Elimination of wolves and panthers have led to increase in their natural prey: deer. There are more deer estimated in the United States than there were when Europeans arrived. Large deer populations often cause over grazing that in turn leads to starvation of the deer.

Introduction of New Species

Introduction of exotic or alien non-native species into new areas is perhaps the greatest single factor to affect natural populations. More than 1500 exotic insect species and more than 25 families of alien fish have been introduced into North America; in excess of 3000 plant species have also been introduced. The majority of accidental introductions may fail, however, once an introduced species becomes established, its population growth is explosive. Kudzu, a plant introduced to the American south from Japan, has taken over large areas of the countryside.

Kudzu covering a building (left) and closeup of the flowers and leaves (right). Images from http://www.alltel.net/~janthony/kudzu/, photographs by Jack Anthony, used with permission.

Altering Population Growth

Humans can remove or alter the constraints on population sizes, with both good and bad consequences. On the negative side, about 17% of the 1500 introduced insect species require the use of pesticides to control them. For example, African killer bees are expanding their population and migrating from northward from South America. These killer bees are much more agressive than the natives, and destroy native honeybee populations.

On a positive note, human-induced population explosions can provide needed resources for growing human populations. Agriculture now produces more food per acre, allowing and sustaining increased human population size.

Human action is causing the extinction of species at thousands of times the natural rate. Extinction is caused by alteration of a population's environment in a harmful way. Habitat disruption is the disturbance of the physical environment of a species, for example cutting a forest or draining wetlands. Habitat disruption in currently the leading cause of extinction.

Changes in the biological environment occur in three ways.

1. Species introduction: An exotic species is introduced into an area where it may have no predators to control its population size, or where it can greatly out compete native organisms. Examples include zebra mussels introduced into Lake Erie, and lake trout released into Yellowstone Lake where they are threatening the native cutthroat trout populations.
2. Overhunting: When a predator population increases or becomes more efficient at killing the prey, the prey population may decline or go extinct. Examples today include big game hunting, which has in many places reduced the predator (or in this case prey) population. In human prehistory we may have caused the

extinction of the mammoths and mastodons due to increased human hunting skill.

3. Secondary extinction: Loss of food species can cause migration or extinction of any species that depends largely or solely on that species as a food source.

Overkill is the shooting, trapping, or hunting of a species usually for sport or economic reasons. Unfortunately, this cannot eliminate "pest" species like cockroaches and mice due to their large population sizes and capacity to reproduce more rapidly than we can eliminate them. However, many large animals have been eliminated or had their populations drastically reduced (such as tigers, elephants, and leopards).

The death of one species or population can cause the decline or elimination of others, a process known as secondary extinction. Destruction of bamboo forests in China, the food for the giant panda, may cause the extinction of the panda. The extinction of the dodo bird has caused the Calviera tree to become unable to reproduce since the dodo ate the fruit and processed the seeds of that tree.

Giant pandas eat an estimated 10,000 pounds of bamboo per panda per year. Image of a giant panda eating bamboo from http://www.bonus.com/contour/Save_our_Earth/http@@/library.thinkquest.org/2988/e-animals.htm#Giant Panda.

Populations Have a Minimum Viable Size

Even if a number of individuals survive, the population size may become too small for the species to continue. Small populations may have breeding problems. They are susceptible to random environmental fluctuations and genetic drift to a greater degree than are larger populations. The chance of extinction increases exponentially with decreasing population size.

The minimum viable population (MVP) is the smallest population size that can avoid extinction by the two reasons listed above. If no severe environmental fluxes develop for a long enough time, a small population will recover. The MVP depends heavily on reproductive rates of the species.

Range and Density

Populations tend to have a maximum density near the center of their geographic range. Geographic range is the total area occupied by the species. Outlying zones, where conditions are less optimal, include the zone of physiological stress (where individuals are rare), and eventually the zone of intolerance (where individuals are not found).

The environment is usually never uniform enough to support uniform distribution of a species. Species thus have a dispersion pattern. Three patterns found include uniform, clumped, and random.

Geographic ranges of species are dynamic, over time they can contract or expand due to environmental change or human activity. Often a species will require another species' presence, for example *Drosophila* in Hawaii. Species ranges can also expand due to human actions: brown trout are now found worldwide because of the spread of trout fishing.

Population Sampling

Ecologists and conservation biologists frequently need to know how a community of organisms is structured. That is, what species compose the community; how abundant is each species; how do the species interact; and are some species increasing in abundance while others are decreasing in abundance over time? Such information is invaluable when biologists develop conservation plans for natural areas or recovery plans for threatened or endangered species. Furthermore, measures of species abundances within a community taken at one point in time provide a baseline against which future measures of species abundances within that community can be compared. Such timelines of community data allow ecologists to measure species changes within communities and to better understand succession within a given natural community or the impacts of specific land-management plans.

The need to assess community structure has generated a number of quantitative field methods as well as an appreciation of which methodology works best in a given situation. These methods are designed to generate reliable estimates of the abundance and distribution of each species within a community. Such data make it possible to compare species or groups of species within a community or to contrast species composition and abundance among communities.

WHY DO WE NEED TO SAMPLE?

If we want to know what kind of plants and animals are in a particular habitat, and how many there are of each species, it is usually impossible to go and count each and every one present. It would be like trying to count different sizes and colors of grains of sand on the beach.

This problem is usually solved by taking a number of samples from around the habitat, making the necessary assumption that these samples are representative of the habitat in general. In order to be

reasonably sure that the results from the samples do represent the habitat as closely as possible, careful planning beforehand is essential.

Samples are usually taken using a standard sampling unit of some kind. This ensures that all of the samples represent the same area or volume (water) of the habitat each time.

The usual sampling unit is a quadrat. Quadrats normally consist of a square frame, the most frequently used size being $1m^2$. The purpose of using a quadrat is to enable comparable samples to be obtained from areas of consistent size and shape. Rectangular quadrats and even circular quadrats have been used in some surveys. It does not really matter what shape of quadrat is used, provided it is a standard sampling unit and its shape and measurements are stated in any write-up. It may however be better to stick to the traditional square frame unless there are very good reasons not to, because this yields data that is more readily comparable to other published research. (For instance, you cannot compare data obtained using a circular quadrat, with data obtained using a square quadrat. The difference in shape of the sampling units will introduce variations in the results obtained.)

ECOLOGICAL SAMPLING METHODS

Many ecological surveys are carried out over extended periods of time, with sampling taking place at regular intervals within a particular habitat. In such cases, it is necessary to estimate the number of samples which should be taken at each sampling period. The minimum number of samples which should be taken to be truly representative of a particular habitat, can be ascertained by graphing the number of species recorded, as a function of the number of samples examined.

Section 3
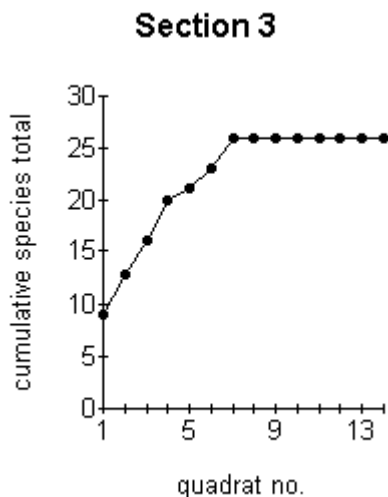
The graph (*left*) is an example of this, obtained from a survey of a heathland area. The first sample yielded 9 different species. With the second sample, a total of 13 species had been found. After 5 samples had been examined, the total species number had risen to 21. By the time 7 samples had been taken, no more new species were being found. At this point, further sampling is becoming unnecessary. This graph therefore shows us that **for this particular habitat,** we need to sample at least 7 samples in each sampling period. Further sampling will merely waste time and duplicate results.

Sampling Methods

Choice of quadrat size depends to a large extent on the type of survey being conducted. For instance, it would be difficult to gain any meaningful results using a 0.5m^2 quadrat in a study of a woodland canopy! Small quadrats are much quicker to survey, but are likely to yield somewhat less reliable data than large ones. However, larger quadrats require more time and effort to examine properly. A balance is therefore necessary between what is ideal and what is practical. As a general guideline, 0.5 - 1.0m^2 quadrats would be suggested for short grassland or dwarf heath, taller grasslands and shrubby habitats might require 2m quadrats, while quadrats of 20m^2 or larger, would be needed for woodland habitats. At the other end of the scale, if you are sampling moss on a bank covered with a very diverse range of moss species, you might choose to use a 0.25m^2 quadrat.
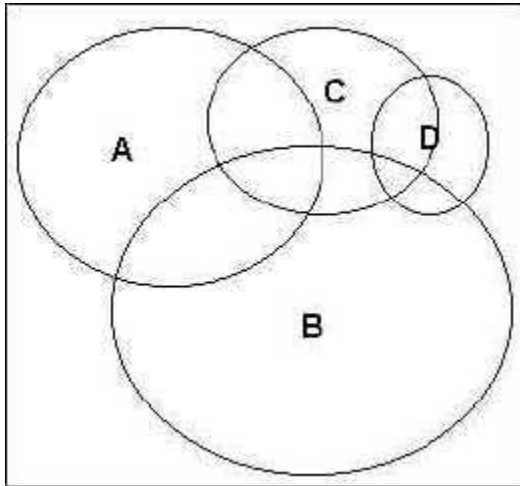
To record percentage cover of species in a quadrat, look down on the quadrat from above and estimate the percentage cover occupied by each species (e.g. species A - D *left*). Species often overlap and there may be several different vertical layers. Percentage cover may therefore add up to well over 100% for an individual quadrat.
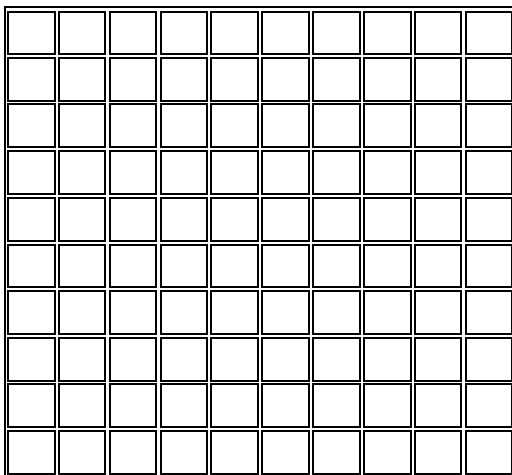
The estimation can be improved by dividing the quadrat into a grid of 100 squares each representing 1% cover. This can either be done mentally by imagining 10 longitudinal and 10 horizontal lines of equal size superimposed on the quadrat, or physically by actually dividing the quadrat by means of string or wire attached to the frame at standard intervals. This is only practical if the vegetation in the area to be sampled is very short, otherwise the string/wire will impede the laying down of the quadrat over the vegetation.

Quadrats are most often used for sampling, but are not the only type of sampling units. It depends what you are sampling. If you are sampling aquatic microorganisms or studying water chemistry, then you will most likely collect water samples in standard sized bottles or containers. If you are looking at parasites on fish, then an individual fish

will most likely be your sampling unit. Similarly, studies of leaf miners would probably involve collecting individual leaves as sampling units. In these last two cases, the sampling units will not be of standard size. This problem can be overcome by using a weighted mean, which takes into account different sizes of sampling unit, to arrive at the mean number of organisms per sampling unit.

There are three main ways of taking samples.

1. Random Sampling.

2. Systematic Sampling (includes line transect and belt transect methods).

3. Stratified Sampling.

Which method to use?

RANDOM SAMPLING
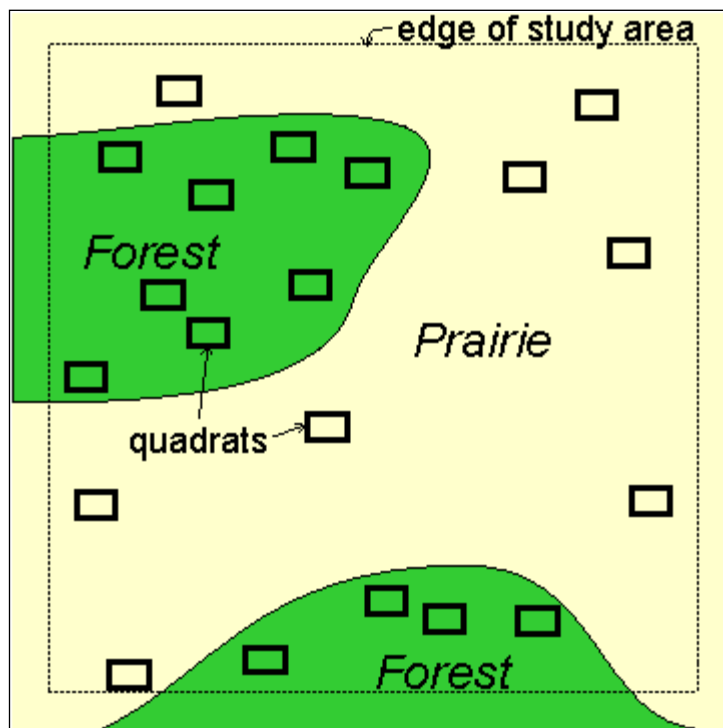
Random sampling is usually carried out when the area under study is fairly uniform, very large, and or there is limited time available. When using random sampling techniques, large numbers of samples/records are taken from different positions within the habitat. A quadrat frame is most often used for this type of sampling. The frame is placed on the ground (or on whatever is being investigated) and the animals, and/ or plants inside it counted, measured, or collected, depending on what the survey is for. This is done many times at different points within the habitat to give a large number of different samples.

In the simplest form of random sampling, the quadrat is thrown to fall at 'random' within the site. However, this is usually unsatisfactory because a personal element inevitably enters into the throwing and it is not truly random. True randomness is an important element in ecology, because statistics are widely used to process the results of

sampling. Many of the common statistical techniques used are only valid on data that is truly randomly collected. This technique is also only possible if quadrats of small size are being used. It would be impossible to throw anything larger than a 1m^2 quadrat and even this might pose problems. Within habitats such as woodlands or scrub areas, it is also often not possible to physically lay quadrat frames down, because tree trunks and shrubs get in the way. In this case, an area the same size as the quadrat has to be measured out instead and the corners marked to indicate the quadrat area to be sampled.

A better method of random sampling is to map the area and then to lay a numbered grid over the map. A (computer generated) random number table is then used to select which squares to sample in. (Random number Table below). For example, if we have mapped our habitat , and have then laid a numbered grid over it as shown (Figure - below) , we could then choose which squares we should sample in by using the random number table.
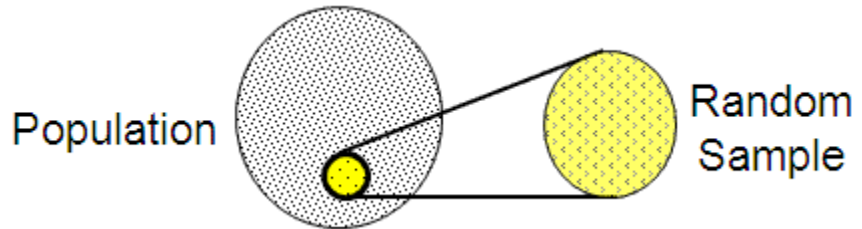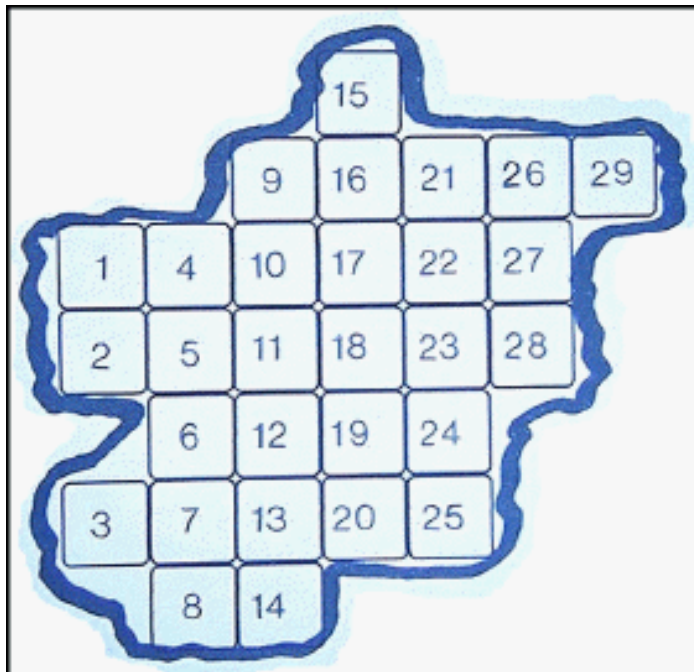
A numbered grid map of an area to be sampled

If we look at the top of the first column in the random number table (below), our first number is 20. Moving downwards, the next two numbers in the random number table would be 74 and 94, but our highest numbered square on our grid is only 29 (Figure above). We would therefore ignore 74 and 94 and move on to the next number which is 22. We would then sample in Square 22. Continuing down the figures in this column, we

would soon come across the number 20 again. As we have already selected this grid for sampling we would similarly ignore this number and continue on to the next. We would continue in this fashion until we had obtained enough samples to be representative of the habitat. There are other methods for selecting numbers from a random number table, but this is the simplest.

In some habitats it may be difficult to set up numbered grids (e.g. in woodland) and in these a 'random walk' may be used. In this method, each sample point is located by taking a random number between 0 and 360, to give a compass bearing, followed by another random number which indicates the number of paces which should be taken in that direction.

RANDOM NUMBER TABLE

20 17	42 28	23 17	59 66	38 61	02 10	86 10	51 55	92 52	44 25
74 49	04 19	03 04	10 33	53 70	11 54	48 63	94 60	94 49	57 38
94 70	49 31	38 67	23 42	29 65	40 88	78 71	37 18	48 64	06 57
22 15	78 15	69 84	32 52	32 54	15 12	54 02	01 37	38 37	12 93
93 29	12 18	27 30	30 55	91 87	50 57	58 51	49 36	12 53	96 40
45 04	77 97	36 14	99 45	52 95	69 85	03 83	51 87	85 56	22 37
44 91	99 49	89 39	94 60	48 49	06 77	64 72	59 26	08 51	25 57
16 23	91 02	19 96	47 59	89 65	27 84	30 92	63 37	26 24	23 66
04 50	65 04	65 65	82 42	70 51	55 04	61 47	88 83	99 34	82 37
32 70	17 72	03 61	66 26	24 71	22 77	88 33	17 78	08 92	73 49
03 64	59 07	42 95	81 39	06 41	20 81	92 34	51 90	39 08	21 42
62 49	00 90	67 86	93 48	31 83	19 07	67 68	49 03	27 47	52 03
61 00	95 86	98 36	14 03	48 88	51 07	33 40	06 86	33 76	68 57
89 03	90 49	28 74	21 04	09 96	60 45	22 03	52 80	01 79	33 81
01 72	33 85	52 40	60 07	06 71	89 27	14 29	55 24	85 79	31 96

27 56	49 79	34 34	32 22	60 53	91 17	33 26	44 70	93 14	99 70
49 05	74 48	10 55	35 25	24 28	20 22	35 66	66 34	26 35	91 23
49 74	37 25	97 26	33 94	42 23	01 28	59 58	92 69	03 66	73 82
20 26	22 43	88 08	19 85	08 12	47 65	65 63	56 07	97 85	56 79
48 87	77 96	43 39	76 93	08 79	22 18	54 55	93 75	97 26	90 77
08 72	87 46	75 73	00 11	27 07	05 20	30 85	22 21	04 67	19 13
95 97	98 62	17 27	31 42	64 71	46 22	32 75	19 32	20 99	94 85
37 99	57 31	70 40	46 55	46 12	24 32	36 74	69 20	72 10	95 93
05 79	58 37	85 33	75 18	88 71	23 44	54 28	00 48	96 23	66 45
55 85	63 42	00 79	91 22	29 01	41 39	51 40	36 65	26 11	78 32

SYSTEMATIC SAMPLING

Systematic sampling is when samples are taken at fixed intervals, usually along a line. This normally involves doing transects, where a sampling line is set up across areas where there are clear environmental gradients. For example you might use a transect to show the changes of plant species as you moved from grassland into woodland, or to investigate the effect on species composition of a pollutant radiating out from a particular source . There are two Systematic sampling methods we can use:

a) Line Transect Method

b) Belt Transect Method

Line Transect Method
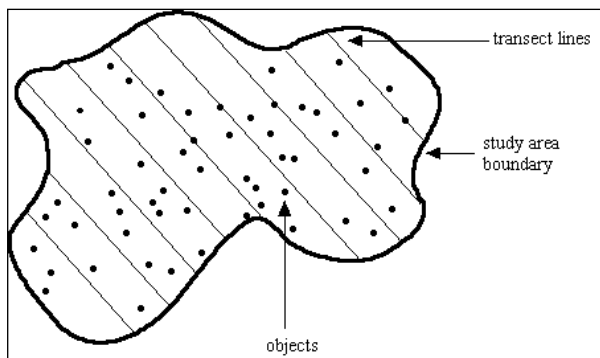
A transect line can be made using a nylon rope marked and numbered at 0.5m, or 1m intervals, all the way along its length. This is laid across the area you wish to study. The position of the transect line is very important and it depends on the direction of the environmental gradient you wish to study. It should be thought about carefully before it is placed. You may otherwise end up without clear results because the line has been wrongly placed. For example, if the source of the pollutant was wrongly identified in the

example given above, it is likely that the transect line would be laid in the wrong area and the results would be very confusing. Time is usually money, so it is worthwhile thinking about it before starting.

A line transect is carried out by unrolling the transect line along the gradient identified. The species touching the line may be recorded along the whole length of the line (continuous sampling). Alternatively, the presence, or absence of species at each marked point is recorded (systematic sampling). If the slope along the transect line is measured as well, the results can then be inserted onto this profile.
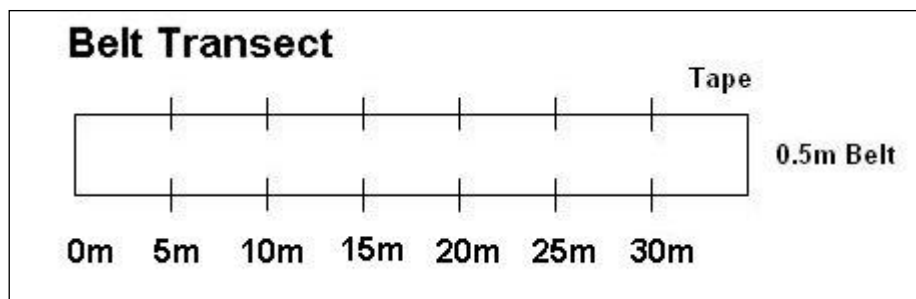
Belt Transect Method
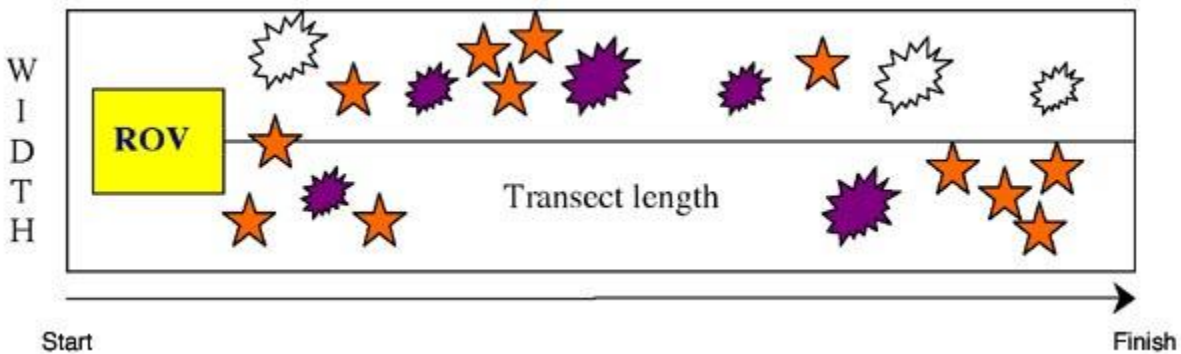
This is similar to the line transect method but gives information on abundance as well as presence, or absence of species. It may be considered as a widening of the line transect to form a continuous belt, or series of quadrats.

In this method, the transect line is laid out across the area to be surveyed and a quadrat is placed on the first marked point on the line. The plants and/or animals inside the quadrat are then identified and their abundance estimated. Animals can be counted (if they will sit still!), or collected, while it is usual to estimate the percentage cover of plant species. Cover is the area of the quadrat occupied by the above-ground parts of a species when viewed from above. The canopies of the plants inside the quadrat will often overlap each other, so the total percentage cover of plants in a single quadrat will frequently add up to more than 100%.

Quadrats are sampled all the way down the transect line, at each marked point on the line, or at some other predetermined interval (or even randomly) if time is short. It is important that the same person should do the estimations of cover in each quadrat, because the estimation is likely to vary from person to person. If different people estimate percentage cover in different quadrats, then an element of personal variation is introduced which will lead to less accurate results. The height of plants in the quadrat can be recorded and the biomass of plants can also be measured by harvesting all the plants inside the quadrat and then weighing either fresh, or dry weight in the laboratory. This is obviously a very destructive method of sampling which could not be used too often in the same place. Sampling should always be as least destructive as possible and you should try not to trample an area too much when carrying out your survey.

An example of the type of results that can be obtained from a belt transect survey is shown below.
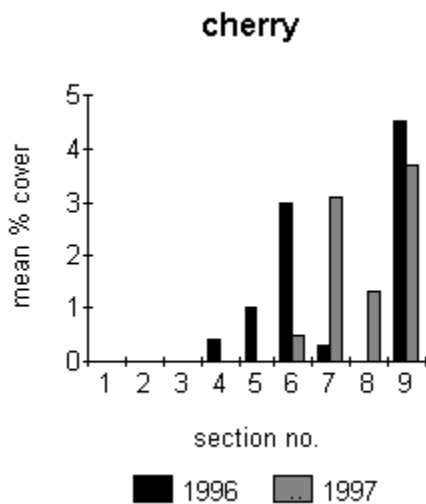
This figure illustrates the distribution and abundance of cherry seedlings along a transect line. The parent cherry trees were adjacent to section number 9. The gradient of distribution apparent in the figure is a result of the dispersal of seeds outwards from this point.

Stratified Sampling
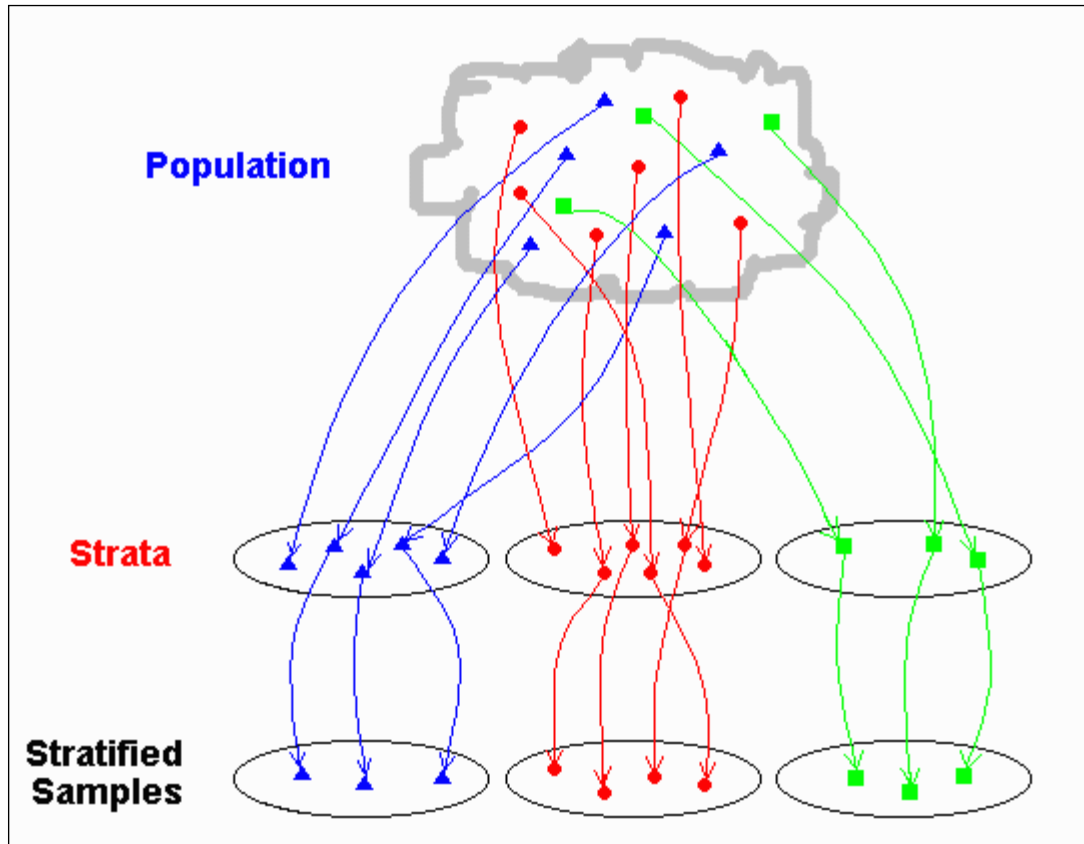
Stratified sampling is used to take into account different areas (or strata) which are identified within the main body of a habitat. These strata are sampled separately from the main part of the habitat. The name 'stratified sampling' comes from the term 'strata' (plural) or stratum (singular). For ease of understanding, the term 'unit' will be used in the following explanation, rather than stratum.

Individual habitats are rarely uniform throughout their extent. There are often smaller identifiable areas within a habitat which are substantially different from the main part of the habitat. For example, scrub patches within a heathland area, or areas of bracken in a grassland.

One of the problems with random sampling is that random samples may not cover all areas of a habitat equally. To continue with the example of bracken patches in a grassland, if the area was random sampled, it is possible that none of the samples might fall within the bracken patches. The results would then not show any bracken in the habitat. Clearly this would not be an accurate reflection of the habitat. In this sort of situation, stratified random sampling would be used to avoid missing out on important areas of the habitat. This simply means identifying the bracken as a different unit within the habitat and then sampling it separately from the main part of the habitat.

While the bracken area clearly needs to be taken into account, it is nevertheless important to avoid overemphasising its significance within the habitat as a whole. Its importance is kept in context by locating a proportional number of samples directly within the bracken unit. The proportion of samples taken within the unit is determined by the area of the unit in relation to the overall area of the habitat.

For example, say the grassland area is 200 m2 overall, with the bracken patch occupying 50 m2 of this total area. The bracken therefore accounts for 25% of the total grassland area. Say it has been decided that a total of 12 samples need to be taken in order to accurately reflect the composition of the whole habitat. Then 3 of those samples (one quarter, or 25%) would be located within the bracken unit and 9 (three quarters, or 75%) in the general grassland area.

There is a standard formula for calculating the number of samples to be placed in each unit. This is:

$$\text{The number of quadrats sampled in the unit} = \frac{\text{the area of the unit} \times \text{the total number of quadrats to be sampled}}{\text{total area of the habitat}}$$

For example, in the illustration given above this would be:

$$3 = \frac{50 \times 12}{200}$$

Which Method to Use?

Stratified Sampling?

Stratified sampling is simply the process of identifying areas within an overall habitat, which may be very different from each other and which need to be sampled separately. Each individual area separately sampled within the overall habitat is then called a stratum. The habitat may be fairly uniform, in which case, this is unnecessary.

Random Sampling?

- This is used where the habitat being sampled is fairly uniform.
- To remove observer bias in the selection of samples.
- Where statistical tests are to be used which require randomly collected data.
- Where a large area needs to be covered quickly.

- If time is very limited.

Systematic Sampling (Transects)?

- To show zonation of species along some environmental gradient. e.g. down a sea shore, across a woodland edge.
- Where there is some kind of continuous variation along a line,
- To sample linear habitats, e.g. a roadside verge.

Where physical conditions demand it, e.g. sampling a vertical rock face, using a rope to climb it.

Systematic Sampling - Line or Belt?

Line Transect?

- Where time is limited. A line transect can be carried out much quicker than a belt transect.
- To visually illustrate how species change along the line. Keys can be chosen to represent individual species. Vegetation height can be drawn in choosing an appropriate scale. The slope of the line can also be measured when carrying out the transect and incorporated into the transect diagram.
- To show species ranges along the line. This will generally show only where the species occurs, not how much of it is present.

Belt Transect?

- A belt transect will supply more data than a line transect. It will give data on the abundance of individual species at different points along the line, as well as on their range.
- As well as showing species ranges along the line, a belt transect will also allow bar charts to be constructed showing how the abundance of each individual species changes within its range.
- Belt transect data will allow the relative dominance of species along the line to be determined.

What interval should be used?

Transects can either be continuous with the whole length of the line being sampled, or samples can be taken at particular points along the line. For example, every meter, or every other meter.

For both line and belt transects, the interval at which samples are taken will depend on the individual habitat, as well as on the time and effort which can be allocated to the survey.

- Too great an interval may mean that many species actually present are not noted, as well as obscuring zonation patterns for lack of observations. Too small an interval can make the sampling extraordinarily time consuming, as well as yielding more data than is needed. This can cause problems with presenting the data (line transects) as well as sometimes making it harder to see patterns of zonation because of too much 'clutter'.
- It is important to make sure that the interval chosen does not happen to coincide with some regularly occurring feature of the habitat. For example, if sampling an old field with ridge and furrow systems still obvious, the interval should not be such that all samples are taken on a ridge, or all the samples in a furrow. (Unless, of course, the purpose of the survey is to identify any differences between ridges and furrows!)
- The ideal interval will be chosen by balancing the complexity of the individual habitat with the purpose of the survey and the resources available to carry it out.

Where to Sample

Three approaches could be used to sample within communities of organisms but as you will learn, these approaches are not equal in their ability to generate reliable estimates of species abundance.

(1) Haphazard or convenience sampling selects samples that are readily available – such samples are almost never random samples. The extent to which community statistics generated from such sampling can be generalized to the community as a whole depends on the degree to which the samples represent the whole. The more homogeneous the community from which our samples are drawn, the more likely haphazard sampling will reliably represent the community. However, the more heterogeneous the community, the more likely such sampling will offer a biased, unrepresentative estimates.

(2) Random sampling ensures that all individuals within a community have an equal chance of being sampled. While this approach is likely to generate reliable estimates of community parameters with sufficient sampling, random sampling can be difficult under field conditions. It could require, for example, that each individual or area within a community be assigned a number and that the numbers to be sampled be selected by a truly random process. A variation of random sampling, referred to as stratified-random sampling, subdivides the community into any number of homogeneous regions, each of which is then randomly sampled.

(3) Under field conditions, replicated systematic sampling is often applied because it avoids bias better than haphazard sampling and it is easier to apply than random

sampling. With systematic sampling the procedure selects, for example, every 30th individual or perhaps areas to be sampled every 30 meters along equidistant transect lines placed across the sampled community. Systematic sampling is not equivalent to random sampling, however, for if there is periodic ordering within the chosen samples systematic sampling may have a larger error than a random sample.

Measures of Species Abundance – Density, Frequency, Dominance, and Importance

Several standard measures of absolute and relative abundance are used to assess the contribution of each species to a community (Barbour et al. 1999). These measures include: density, the number of individuals within a chosen area (e.g., m2, hectare); relative density, the density of one species as a percentage of total density; frequency, the percentage of total quadrats or points that contains at least one individual of a given species; relative frequency, the frequency of one species as a percentage of total frequency; dominance, the total basal area of a given species per unit area within the community; relative dominance, the dominance of one species as a percentage of total dominance; and importance, expressed as the relative contribution of a species to the entire community expressed as a combination of relative density, relative frequency, and relative dominance (see the Appendix for mathematical definitions of each measure).

Think carefully about the meaning of each of these measures – each offers a different insight into the abundance of the species composing a community. Saplings, for example, typically have a much higher density but much lower dominance than mature trees. Density tells us the number of individuals per unit area but density is not necessarily proportional to dominance because dominance for a given species expresses the area occupied by the species per unit area (e.g., per m2). A species composed of primarily large individuals can have high dominance but it will likely have low density, and unless regularly distributed, it will also have low frequency. Frequency, which is often independent of density, expresses one measure of the distribution of individuals within the community. A clumped species can have high density but also low frequency because it occurs in a limited portion of the community. In contrast, a species that is individually and regularly distributed over the landscape will have a high frequency but can have low density. Relative importance, as a combination of relative values for density, frequency, and dominance, is used as a summary of the influence that an individual species may have within the community. Recognize that two species with the same relative importance can have markedly different values for relative density, frequency, or dominance as any differences can be overshadowed by the addition process (Barbour et al. 1999).

Measures of Distribution

Individuals of a species can be randomly distributed across a community (i.e., the location of one individual of a given species has no relationship with the location of other individuals of that species). Individuals of other species might be singly and

regularly distributed throughout the community (an extreme example is the uniform spacing of orchard trees), while the individuals of still other species could be clumped (i.e., the presence of one individual of a given species increases the probability of finding another individual of that species nearby). Thus, ecologists recognize three primary patterns of distribution:

(1) random,

(2) regular (uniform) or hyperdispersed, and

(3) clumped (aggregated) or underdispersed (Barbour et al. 1999).

There are a number of reasons why plants show clumped distributions. Many plants are highly clonal (i.e., they can propagate by vegetative means as do goldenrods and aspens) so once a seedling establishes at a given site, the plant spreads to produce numerous, spatially separated (but genetically identical), aboveground stems. In addition, environmental gradients are common in nature so that a site that is good for one individual of a given species is likely to be good for other individuals of that species. Yet there are forces in nature that counteract clumping. Competition among individuals for water in deserts or light in forests can favor regular spacing. Similarly plants that are clumped are more likely to be found by their herbivores or pathogens (Barbour et al. 1999).

Measures of Richness, Evenness, and (Species) Diversity

Species richness [the number of species occurring within a specific area or community], species evenness or equitability [the distribution of individuals among species], and species diversity [typically measured as a combination of species richness and species evenness; that is, species richness weighted by species evenness, see Appendix] are measures unique to the community level of ecological organization (Barbour et al. 1999). These statistics reflect the biological structure of a community. A community with high species richness and diversity, for example, will likely have a complex network of trophic pathways. In contrast, a community with low species richness and diversity will likely have fewer species and trophic interactions. Interactions among species (e.g., energy transfer, predation, competition) within the food webs of communities with high species diversity are theoretically more complex and varied than in communities of low species diversity. Indices of species richness and species diversity are often used in a comparative manner, that is, to compare communities growing under different environmental conditions or to contrast seral stages of a succession.

ACTIVITY: SOMETHING'S FISHY: A LESSON IN BIOLOGICAL SAMPLING

DURATION: 2 hours

OBJECTIVES

- Use proper scientific method and sampling techniques.
- Explain the methods used to determine the population in a particular area.
- Use math to calculate percent error.
- Explain additional population sampling methods.
- Students will evaluate the importance of research versus danger to the habitat of the population.

MATERIALS

- Goldfish crackers
- colored goldfish or pretzels
- lab sheet (attached)
- Computer with Internet
- presentation software
- calculators

BACKGROUND/PREPARATION

Students need to have a prior knowledge of sampling and populations. Students need to understand the need for determining population size. Brief overview is included on worksheet. They also need basic algebra, the definition of population, understanding for the need of knowing population size and possible methods of determining population size.

PROCEDURES

1. Students are divided into groups based on learning style and ability.
2. Student receive "Something's Fishy lab sheet"
3. Students complete the lab.
4. Students complete statistics portion of lab.
5. Students complete problems and discussion in groups. Turn in one answer sheet per group.
6. Students use the Internet to find 3 populations for which this method of determining size would work.
7. Students find one population for which this method of determining size would not work and explain the reason it would not work.

8. Students evaluate other methods of determining population size. They must give two ways and one example of each.
9. Results are presented to the class in the form of a PowerPoint.

SOMETHING'S FISHY

Statistics of repeated "large" samples of a population will vary in a regular and predictable pattern from the real population parameter that we are trying to measure. The mean (average) of our simple statistics, however, should approximately equal the population parameter that we are trying to measure is we use proper scientific methods and are careful to take many random samples.

BIOLOGICAL SAMPLING

How do biologists determine the population of a species in a particular area? There are a variety of ways that it can be done; however, the most common method involves tagging. In this method, biologist first capture and tag a sample of the animals. Then, after some time has passed the animals are returned and allowed to "redistribute" themselves. The scientists, then take repeated random samples and estimate the total population.

FISHING EXERCISE

Each of the teams in class has population of cheddar "goldfish" in front of them. Your goal is to approximate the size of your population using the same tagging and sampling methods that biologists use.

1. Remove a sample (a large handful of fish, approximately 40). Replace this sample with the equivalent number of tagged fish (pretzel or colored goldfish). Record in the table how many you "tagged".

2. Mix the population thoroughly to get the tagged fish "redistributed" among the population.

3. Without looking (to prevent your personal bias) remove a sample of fish from the "pond". Count the number of tagged and total number of fish in your sample, recording these numbers.

4. Mix the populations thoroughly and repeat the sampling for a total of 20 samples. The sample sizes do not have to remain the same, but you do want to get fairly large handfuls each time of fish.

RESULTS

SAMPLE	# OF TAGGED FISH IN SAMPLE	TOTAL SAMPLE SIZE
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
MEAN =		

INFERENTIAL STATISTICS

How do we predict the population size? If a specific number of individuals are captured, marked, and released into the wild population, it is possible to estimate the total population using the following ration:

$$\frac{\text{POPULATION SIZE}}{\text{NUMBER ORIGINALLY TAGGED}} == \frac{\text{TOTAL SAMPLE SIZE TAKEN OUT}}{\text{NUMBER OF TAGGED FISH IN SAMPLE}}$$

$$\text{POPULATION SIZE} = \frac{\text{TOTAL SAMPLE SIZE TAKEN OUT}}{\text{\# OF TAGGED FISH IN SAMPLE}} \times \text{\# ORIGINALLY TAGGED}$$

Using your information, find the predicted size for your pool: _____

Now, count your entire population and determine how close your estimate was.

Actual population: _____

Percent Error = $\underline{\text{Estimated Population}}$ X 100 =
                 Actual Population   _____

PROBLEMS AND DISCUSSION

1. What could cause your results to be off from the actual population?

_____
_____
_____

2. How would sample size and population size affect these results?

_____
_____
_____

3. How would the number of samples affect these results?

_____
_____
_____

4. If you were predicting a large population (as in a real pond) would the number you were off really have been that bad, relatively speaking?

_____
_____
_____

5. What concerns should biologists have about a species' habitats before he / she uses this method to approximate the size of the population?

_____
_____
_____

6. Even with these concerns, does this mean that tagging should not be used by biologists?

_____
_____
_____

7. Are there other uses of tagging?

_____
_____

ACTIVITY: TRANSECT INVESTIGATION

DURATION: 2 hours or 2 class period.

OBJECTIVES

Students will be able to:
- Subdivide an area into transects and perform a scientific study.
- Use a magnetic compass to determine the N/S and E/W directions in the transect.
- Grid the transect and transcribe the biotic and abiotic information accurately on paper.
- Create their own map scale.
- Combine class transect data and make some general conclusions about the area.
- Predict how a drought and flood rains might affect the area.

MATERIALS

- outside area such as a park, meadow, or forest
- string
- wooden pegs
- meter stick
- paper
- red, green, and blue colored pencils
- compass
- copy of Transect Study activity sheet
- poster board

BACKGROUND INFORMATION

One method scientists use to study an environment more closely is to divide the area into smaller plots called transects. A scientist can record the location and number of different animal and plant species that occur in the transect. Abiotic (nonliving) factors can also be recorded depending on the level of detail required by the study. If the area is rather homogeneous (the same throughout) fewer transects need to be analyzed in order to draw some general conclusions about the area. The more varied the area the more transects need to be analyzed in order to make accurate general conclusions.

For some species such as certain weeds (like dandelions) it may not be realistic to count the number of individual weeds in the entire transect since their number is so large. In such cases a tiny area of the transect can be selected where the weed is counted and then by the use of multiplication the scientist can calculate the estimated number of weeds that occur in the transect (since the weed growth pattern is not identical   throughout   the   area).

PROCEDURE

1. Organize students into groups and provide them with a copy of the Transect Study activity sheet.
2. Assign each group a transect (an area of five feet by five feet) to study. Have students stake out their area using the wooden pegs and rope. Identify each transect by number.
3. Using the compass have students determine their N/S, E/W orientation and record this information on their activity sheet.
4. Have students `grid' their transect by using the pegs and string. For example, they may put a string across the transect every foot both in the north/south direction and in the east/west direction. In this way they can more accurately locate the geographical features on their transect as they record them on their activity sheet.
5. Students should pick out and record the most distinguishing features first. They should record what they see (naming the species if possible) and the amount of what they see.
6. Students should use the colored pencils to indicate grass (green), water (blue), and soil (brown).
7. Have students note any effects on their transect due to human activity.
8. Return to the classroom and combine all the transects together on a poster board, synthesizing the information into one document describing the area of study.
9. Have students comment on the following:
   o What generalizations can they make about the area?
   o When all the transects were combined, was the area the same throughout or different and why?
   o Did they see any effects of human intervention on their transect? Was it harmful or beneficial?
   o How does the area get water? How would the area withstand a drought? Flood rains?
   o Is the area in danger of dying out? If so, what is the threat and how soon? Is there anything that can be done to prevent death to the area?

Transect Study

Student investigator: _____

Students in my group:

_____   _____

_____   _____

Transect number:_____

Geographical orientation (N/S, E/W):_____

Transect Scale: 6 inches = _____ on the transect map

Procedure

As you study your transect comment on the following:

1. Is your area the same throughout or different and why?

    _____

    _____

2. Are there any generalizations you can make? What are they?

    _____

    _____

3. Do you see any effects of human intervention on your transect? Is it harmful or beneficial?

    _____

    _____

4. How does your area get water? How would the area withstand a drought? Flood rains?

    _____

    _____

5. Is the area in danger of dying out? If so, what is the threat and how soon? If yes is there anything that can be done to prevent destruction to the area?

    _____

    _____

ACTIVITY: CAPTURE-RECAPTURE

In this lesson, students experience an application of proportion that scientists actually use to solve real-life problems. Students learn how to estimate the size of a total population by taking samples and using proportions. The ratio of "tagged" items to the number of items in a sample is the same as the ratio of tagged items to the total population.

DURATION: 2 hours

OBJECTIVES

By the end of this lesson, students will:

- Recognize equivalent ratios
- Determine good and poor estimates
- Solve proportions to estimate population size

MATERIALS

- Paper cup
- Handful of white beans
- Marker for marking the beans
- 'Capture-Recapture' Activity Sheet

PROCEDURE

Students should be comfortable with the definitions of and distinctions between a ratio and a proportion. Review of these topics may be a valuable warm-up for students.

Students should already have a method for solving a proportion. For example:

1.   Solve: 11/15 = x/75.

2.   James knows that 2/3 of the class is going on the field trip. If 24 students go on the trip, how many students are in the class?

BEFORE CLASS

Prepare the cups of beans. Each group/pair of students should receive their own cup of unmarked beans. The cups should have more beans than can be counted visually (around 200). The cups may have the same number of beans, or they may be different, depending on your preference.

IN CLASS

1. Introduce the lesson with a discussion about the following situation:

Scientists often study the health of a habitat by gathering data about the number of animals that live in the area. Suppose you wanted to know how many robins lived in a particular forest.

2. Ask students how they think the number of robins in a forest could be counted.

- Elicit student responses to questions such as:If you tried to gather all of the robins and count them, how would you know if you had indeed counted every single one?
- Do you need to know the exact number of robins?

3. To begin the activity, distribute the Capture-Recapture activity sheet, a cup full of white beans, and a marker to each pair or group of students.

4. Emphasize for students that:

- An initial handful of beans must be marked, counted, **recorded on the activity sheet for Question 1** and returned to the cup at the beginning of the activity.

- After each sampling and counting (for trials 1 through 6), all the beans are returned to the cup before the next trial.

- Although the steps to be taken are outlined on the activity sheet, you may want to walk students through filling out one of the rows. For instance, if a handful of 33 beans is pulled from the cup and 6 beans are marked, then the first row of the table in Question 5 would be filled out like this:

TRIAL NUMBER	NUMBER OF MARKED BEANS	TOTAL NUMBER OF BEANS	RATIO OF MARKED TO TOTAL	
1	6	33	6/33	
2				

5. When students complete the activity with the beans, they may need some guidance for setting up their first proportion (in Question 7). Model for them what is being compared, and develop a model to estimate the total population when the sample tagged, sample size, and total tagged are known.

$$\frac{\text{marked in sample}}{\text{total in sample}} = \frac{\text{marked in cup}}{\text{total in cup}}$$

For example, suppose that they initially marked 42 beans. Then, the proportion would be 6/33 = 42/x for the first trial. In Question 8, the activity sheet would then be filled in as follows:

TRIAL NUMBER	NUMBER OF MARKED BEANS	TOTAL NUMBER OF BEANS	RATIO OF MARKED TO TOTAL	Est. Total
1	6	33	6/33	231
2				

8. Students should write and solve a proportion representing each trial with the beans. Their results won't be perfect, but most answers should fall within a reasonable range of the actual number of beans in the cup.

9. As students finish their calculations, have them write their answers to the remaining questions on the activity sheet. This will enrich the responses that students might give to the Questions For Students that you may wish to ask to the entire class.

10 After Guessing the Total Number of Beans In Question 14 of the activity sheet, students are asked to examine the process and think about what would make an acceptable estimate. Students should take additional samples and then determine what percent of their population estimates fall within the interval they say is acceptable. By doing this, students have a frame of reference to determine if an estimate is good or poor. They can look at the distribution of their estimates and be fairly certain that the estimates that are at either end of the range of distributions are likely to be poor. As a class, choose one group's work, build a bar graph on the board, and discuss the group's results.

11. If there's time before the end of the period, ask students to count the total number of beans in their cup to check their answers. Students should be discouraged from counting the beans instead of using proportions during the activity, but once they've committed to an answer, they can count the *actual* number of beans in the cup to know how reasonable their calculated estimate is.

Questions for Students

1. How do proportions help solve the problem of counting robins in the forest?

Answer: [If the scientists capture and tag a specific number of robins, then they can recapture robins later and use a proportion to estimate the total number of robins in the forest.]

2. What might happen if a small number of robins in the population are tagged?

Answer: [When a sample is taken it is possible that no tagged robins will be in the sample and the resulting calculation suggests that there are no robins in the forest.

3. What might happen if almost the entire population of robins is tagged?

Answer: [When a sample is taken, it is possible that all of the tagged robins will be in the sample. The resulting calculation would then underestimate the number of robins in the entire population.]

4. Develop a plan to estimate the size of the populations of more that one species from one sample.

Answer: [Mark each species with a different color. For each species, use a proportion to compare the number of marked to the sample size and the total marked to the population.]

Population Estimation with Capture and Recapture

Student worksheet

Name:_____

The idea behind capture and recapture is:

- Capture and tag some birds in a forest, allowing each of them to go free after being tagged.
- Recapture a set of birds from the forest, and count how many from that set are tagged.
- Use the ratio of tagged birds in your set to generate a proportion. Use the proportion to estimate the total population of birds in the forest.

Procedure

1. From the cup, CAPTURE a handful of beans. Count the number of beans that you've captured. Mark each of them with a marker. How many beans did you mark? (This number will be important for Questions 8 and 9.)

2. Put the marked beans back in the cup and shake up the cup.

3. From the cup, RECAPTURE a new handful of beans. How many total beans are in your new handful? _____ How many marked beans are in your new handful? _____

4. Write a ratio representing marked beans (in handful) : total beans (in handful)

5. Fill in the three labeled columns in the first row (across) of the table, using your answers from Questions 3 and 4. (For now, leave the grey column blank; you will fill it in for Question 9.)

TRIAL NUMBER	NUMBER OF MARKED BEANS	TOTAL NUMBER OF BEANS	RATIO OF MARKED TO TOTAL
1			
2			
3			
4			
5			
6			

Activity: Random Sampling

Introduction

Scientists cannot possibly count every organism in a population. One way to **estimate the size of a populatio**n is to collect data by taking random samples. If you survey *every person* or a *whole set of units* in a population you are taking a *census.* However, this method is often impracticable; as it's often very costly in terms of time and money. For example, a survey that asks complicated questions may need to use trained interviewers to ensure questions are understood. This may be too expensive if every person in the population is to be included.

Sometimes taking a census can be impossible. For example, a car manufacturer might want to test the strength of cars being produced. Obviously, each car could not be crash tested to determine its strength!

To overcome these problems, *samples* are taken from populations, and **estimates** made about the total population **based on information derived from the sample**. A sample must be large enough to give a **good *representation*** of the population, but small enough to be manageable. Data obtained by random sampling can be compared to data obtained by actual counts. By comparing data from random sampling to the actual count, you **can compute the percentage error** to determine the accuracy of the random sampling.

Objective

- The size of a population can be determined using the random sampling method.

Materials

- Pencil
- Scissors
- Sheet of paper
- 2 envelopes

Procedure

1. Tear a sheet of paper into 20 slips, each approximately 4cm x 4 cm.
2. Number 10 of the slips from 1 to 10 and put them in an envelope.
3. Label the remaining 10 slips from A through J and put them in a second envelope.
4. Use the grid below for you random and actual counts. The grid represents a meadow measuring 10 meters on each side. Each grid segment is 1m x 1m. Each black circle represents one sunflower plant.
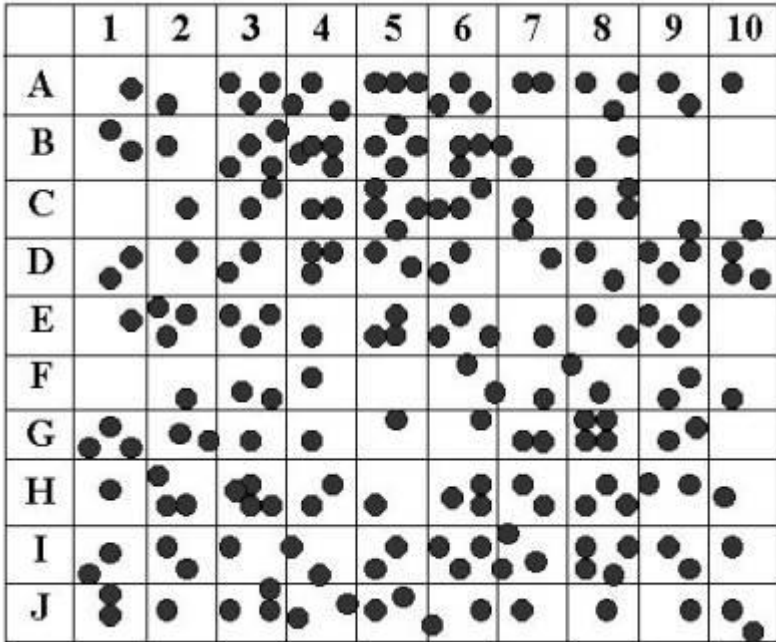
5. Randomly remove one slip from each envelope. Write down the number-letter combination and find the grid segment that matches the combination. Count the number of sunflower plants in that grid segment. Record this number on Data table 1. Return each slip to its appropriate envelop.

6. Repeat step 5 until you have data for 10 different grid segments (and the table is filled out). These 10 grid segments represent a sample. Gathering data from a randomly selected sample of a larger area is called sampling.

7. Find the total number of sunflower plants for the 10 segment sample. This is an estimation based on a formula. Add all the grid segment sunflowers together and divide by ten to get an AVERAGE number of sunflower plants per grid segment. Record this number in the table.   Multiple the average number of sunflower plants by 100 (this is the total number of grid segments) to find the total number of plants in the meadow based on your sample. Record this number in Data Table 1.

8. Now count all the sunflower plants actually shown in the meadow. Record this number in Data Table 2. Divide this figure by 100 to calculate the average number of sunflower plants per each grid.

Data Table 1

Random Sampling Data	
Grid Segment (number-letter)	**Number of Sunflowers**
Total Number of Sunflowers	
Average per grid (divide total by 10)	
Total number of plants in meadow (multiply average by 100)	

Data Table 2

Actual Data	
Total number of Sunflowers (count by hand)	
Average number of Sunflowers (divide total by 10) Per grid	

QUESTIONS

1. Compare the total number you got for sunflowers from the SAMPLING to the ACTUAL count. How close are they?

_____

_____

2. Why was the paper-slip method used to select the grid segments?

_____

_____

3. Why do biologists use Sampling?   Why can't they just go into the forest and count all the sunflower plants?

_____

_____

4. Population Sampling is usually more effective when the population has an *even dispersion* pattern. *Clumped dispersion* patterns are the least effective. Explain why this would be the case.

_____

_____

5. Describe how you would use Sampling to determine the population of dandelions in your yard.

_____

_____

6. In a forest that measures 5 miles by 5 miles, a sample was taken to count the number of silver maple trees in the forest. The number of trees counted in the grid is shown below. The grids where the survey was taken were chosen randomly. Determine how many silver maple trees are in this forest using the random sampling technique. Show your work!

	7			
			3	
			5	
11		9		

RESOURCES

http://www.departments.bucknell.edu/biology/courses/biol208/EcoSampler/
http://www.countrysideinfo.co.uk/howto.htm
http://www.wisegeek.com/what-is-a-population-sampling.htm
http://www.emc.maricopa.edu/faculty/farabee/biobk/biobookpopecol.html
http://en.wikipedia.org/wiki/Population_ecology
http://mansfield.osu.edu/~sabedon/campbl52.htm
http://www.eoearth.org/article/Population_ecology
http://home.comcast.net/~sharov/PopEcol/popecol.html
http://www.pbs.org/fmc/lessons/lesson4.htm
http://www.usc.edu/org/cosee-west/LessonPlans/MLPA%20lesson%20plans/Carolyn%20Newkirk_Wildlife%20sampling.pdf
http://alex.state.al.us/lesson_view.php?id=24094
http://www.pbs.org/wgbh/nova/madagascar/classroom/l3_intro.html
http://www.rsscse.org.uk/ts/gtb/johnson3.pdf
http://www.georgiastrait.org/?q=node/617
http://illuminations.nctm.org/LessonDetail.aspx?id=L721
http://www.biology.ccsu.edu/penniman/Intertidal/MAIN.HTM
http://www.accessexcellence.org/AE/ATG/data/released/0534-KathyParis/index.php
http://www.lessonplansinc.com/lessonplans/population_ecology_lab.pdf
http://www.biologycorner.com/worksheets/biodiversity.html
http://www.usask.ca/education/coursework/mcvittiej/resources/redlily/secondary/pdf/population_samplinglab.pdf
http://www.biologycorner.com/worksheets/predator_prey_graphing.html
http://www.nclark.net/Populations
http://www.biologyjunction.com/random_sampling.htm