JUNTOS

UNIT TWO

A DYNAMIC BALANCE: LIVING IN THE SONORAN DESERT

THE SCIENCE OF CONNECTIONS
ECOLOGICAL INTERACTIONS IN THE SONORAN DESERT

LESSON OVERVIEW

Ecological interactions between organisms contribute to the dynamic balance in ecosystems. In this activity, students are introduced to a variety of ecological interactions which occur among organisms -- specifically Sonoran Desert organisms. The lesson begins with several "hands-on" examples which will allow students to observe real cases of ecological interactions (such as symbiosis, predation, and competition) using such props as insect galls, desert mistletoe, chewed leaves, or a variety of other examples (suggested in the activity). Following a review and discussion of the basic types of ecological interactions among organisms, students will receive *Sonoran Desert Interaction Cards* upon which are described different ecological interactions which actually occur among Sonoran Desert organisms. Students will work in pairs to review their *Sonoran Desert Interaction Cards* and complete a study guide about the interacting organisms. Students will share their findings with the rest of the class. By studying actual interactions between Sonoran Desert organisms, students will become better acquainted with both the interactions and the organisms involved.

TEACHER PREPARATION

✓ Be sure each student has a copy of the following: Student Activity - Study Guide: *Profiles of Sonoran Desert Interactions* and Background Information Fact Sheet: *Ecological Interactions in the Sonoran Desert*
✓ From your neighborhood or schoolyard, collect natural items to use as props to demonstrate desert interactions. Have at least 3 different examples. A list of ideas is provided in the box insert on this page.
✓ Review the Background Information Fact Sheet: *Ecological Interactions in the Sonoran Desert* and assaign this as background reading for your students
✓ Make copies of the Sonoran Desert Interaction Cards (one copy for each pair of students)
✓ Cut out interaction cards and have them ready to hand to pairs of students.
✓ Have ready, an overhead projector
✓ Have ready, the overhead transparency master: *Ecological Interactions*

<u>Examples of Sonoran Desert Interactions</u>

predator - prey interactions
- chewed leaves - herbivory is considered predation on plants
- spider web
- insect parts (the rest may have been eaten by something)
- scat with obvious contents (fur, bones, etc.)

symbiosis
- any kind of flower (to discuss pollination = mutualism)
- paloverde or mesquite bean pod (it indicates that the flower was pollinated - likely by an insect such as a bee = mutualism)
- lichen (fungi and algae living together = mutualism)
- gall from oak, creosote, etc. (although sometimes considered parasitic, many galls formed by insects do not harm the host plant = commensalism)

parasitism
- mesquite branch with mistletoe attached
- prickly pear pad with cochineal
- dog ticks (keep in a closed container)
- mesquite or paloverde bean pods with holes

competition
- any kind of seed - all kinds of animals compete for seeds to eat
- a saguaro " boot" - Gila woodpeckers, flickers, starlings, and house finches all compete for nest space in saguaros

LEARNING OBJECTIVES

Upon completion of this activity, students will be able to:
- use observation skills to identify examples of ecological interactions.
- define and describe predation, competition, mutualism, commensalism, parasitism, and symbiosis.
- describe at least two types of symbiotic relationships and give real-life examples using Sonoran Desert organisms.
- draw a food chain involving Sonoran Desert organisms to depict energy flow through the ecosystem.

TIME NEEDED

This activity may be completed within one class period. However, depending on the time devoted to student sharing of interactions, part of a second class period may be necessary.

MATERIALS NEEDED

- Overhead projector
- Overhead transparency master: *Ecological Interactions*
- A small collection of natural objects to serve as real life examples of Sonoran Desert interactions (see box insert)
- *Sonoran Desert Interaction Cards*
- Student Activity - Study Guide: *Profiles of Sonoran Desert Interactions*
- Background Information Fact Sheet: *Ecological Interactions in the Sonoran Desert*

CURRICULUM TIES

Arizona: 3SC-P4; 4SC-P4
O'odham: A.4.3; A.6.3; B.7.2

TEACHING STRATEGY

1. Introduce and review ecological interactions. Introduce this activity by explaining that it is the first lesson of Unit 2 which focuses on the dynamic balance of ecosystems -- ecological interactions play a big role in that dynamic balance. Introduce and review ecological interactions using the overhead transparency master as your guide. You might instruct students to copy the definitions on their own paper as you conduct the review. Be sure to point out the (+), (-), and (0) system of identifying the interaction by how the involved organisms are affected.
2. Share desert interaction props. Have your "hands-on" examples ready to share with students as you review that specific interaction (e.g., pass around a branch of mesquite with mistletoe in it as you discuss parasitism).
3. Hand out Interaction Cards and explain activity. Pass out copies of the Sonoran Desert Interaction Cards, one card to each pair of students. Students should also have out their copies of their Student Activity - Study Guide: *Profiles of Sonoran Desert Interactions* . Have students work in pairs to review their assigned interaction card and complete their study guides. The study guide has questions about the students' assigned organisms but also has questions which require the students to interview other student pairs in order to gain information about a variety of Sonoran Desert organisms.
4. Student sharing. Ask for volunteers who think they have a really neat interaction to share it with the rest of the class. Continue asking for volunteers to share their interactions until at least one example of each of the five different types of ecological interactions have been reviewed. For further sharing ideas, consider the activity extension, "*Name that Interaction*," described below.
5. Wrap up activity. Conduct a closing discussion using selected questions from the Student Activity - Study Guide: *Profiles of Sonoran Desert Interactions* as prompters. Be sure to tell students that because some interactions are so complex, it is often difficult to name the exact interaction taking place. It is OK if students cannot always identify the specific interaction. However, they should be aware that interactions are constantly taking place between organisms to the benefit of some and the detriment of others. It is important to remind students that the underlying lesson here is about how the interactions contribute to the dyamic balance of the entire ecosystem. Also, it is true, as several wise individuals have suggested, that "everything is connected."

EXTENSIONS

Name that Interaction. Play a game similar to "Charades" in which the class must guess the interactions of the other students' organisms. We suggest you conduct the activity as follows (although adaptations of the activity to suit your class's needs are encouraged):

- Give student pairs around 10 minutes (or more if necessary) to review their cards and plan a presentation to the rest of the class. Encourage creativity in their presentations (ideas include drawings, reading, storytelling, reporting, acting out the organisms, etc.). The key elements they should try to convey are the type of interaction occurring and which organisms are benefiting or not benefiting by the interaction.
- Allow each pair of students to present their interaction to the class.
- The goal is for the rest of the class to guess the specific interactions taking place between the various organisms. The answer should include not only the interaction but which organisms are benefiting or not benefiting. It may be easier for students to guess the type of interaction after they consider the benefits to each organism.
- The class may choose to make ground rules such as: "no shouting out the interaction until the presentation is over;" "teams must begin by stating the identity of their organisms;" and "each team has 2 minutes for their presentation."

Further Investigations. Have students conduct further research on the organisms involved from their assigned Interaction Card. They might find out more about the organism's life histories, create scientific illustrations, or investigate the occurrence of the organisms in the local environment.

Interactions Nature Walk. Take a walk around the school campus to discover different ecological interactions taking place right outside your classroom. You may want to conduct a preliminary "scouting" walk by yourself and locate interaction sites to return to with the students. Its OK if you're not positive what the interaction is, just point out that an ecological interaction is occurring between different organisms. Students may want to spend more time observing the involved organisms to better understand what kind of interaction is occurring.

Food Web Game. Conduct a "Food Web" game as follows. Have ready a lengthy ball of yarn or string. Students may either stand in a circle or remain seated at their desks. One student says the name of a plant or an animal that has been recently discussed (from this or previous lessons). Give that student the end of the string. Have another student come up with a plant or animal that has some kind of interaction with the first organism. As that student says the name and interaction of their plant or animal, unroll the string and, with the first student still holding the end, hand the string to the second student, demonstrating the connection between the two organisms. Have another student come up with an organism that has an interaction with the last organism and unroll the string to add that student to the web, and so on until everyone has thought of an organism and is connected.

ECOLOGICAL INTERACTIONS IN THE SONORAN DESERT

The term "ecological interactions" is used to describe the interrelationships between two or more species. Few, if any, organisms live without some kind of interaction with other organisms. Plants and animals have developed numerous interactions with each other to aid in their survival. Through these interactions, organisms live, die, become very successful (proliferate and have numerous offspring), barely get by (maybe don't even get to breed), or even, get completely wiped out.

Energy Flow

One way that organisms interact is through feeding relationships. When a cottontail rabbit eats grass, it is obtaining energy from the grass. The grass originally obtained that energy from the sun and through photosynthesis, converted it to carbohydrates which are a form of energy that animals can consume and use. Should a red-tailed hawk come along and eat the cottontail, that hawk would gain energy from the rabbit, which had gained energy from the grass, which had gained energy from the sun. This feeding relationship is commonly called a food chain. Food chains describe the flow of energy through ecosystems. Food chains are typically more complex and involve numerous species eating and being eaten by other species. The term "food web" more accurately describes the complex feeding relationships in an ecosystem.

In the case of feeding relationships, it is relatively easy to see that one organism benefits from the relationship (the predator gains energy) and the other organism does not benefit (the prey dies). However, there are numerous other kinds of interactions in which organisms benefit in other ways. Sometimes these interactions aid both organisms, sometimes they aid only one of the organisms, and sometimes, they aid one organism while the other is harmed or even killed.

Symbiosis

When two or more species are involved in a close, long-term relationship, the interaction is called a symbiotic relationship. Although they are not always easy to distinguish, there are several types of symbiotic relationships. When both species benefit from an interaction, it is called mutualism. An example of mutualism involves the soap-tree yucca plant and the yucca moth. The soap-tree yucca, which lives in the Sonoran Desert, can only be pollinated by one animal, the yucca moth. The yucca moth lays its eggs in the flower of the yucca and the larvae grow up eating the ripening seeds of the yucca. As it deposits its eggs in the flower, it also pollinates the plant. The moth lays it eggs nowhere else and the yucca is pollinated only by the yucca. Through this complex relationship, both species rely on each other to survive. This is a mutualistic relationship.

Commensalism

Sometimes in a symbiotic relationship, one species benefits while the other appears unaffected. Such a relationship is called commensalism. A Sonoran Desert example of commensalism is the relationship that exists between the Gila woodpecker and a saguaro. The Gila woodpecker excavates a cavity into the flesh of the saguaro. The saguaro is able to create scar tissue around the hole and appears to be otherwise unaffected by the Gila woodpecker's activity. The Gila woodpecker uses the cavity as a nest site. Although Gila woodpeckers use other cavities as nest sites, the commensal relationship between them and the saguaro is a long-term one, enduring over hundreds, perhaps thousands of years.

Parasitism

Another relationship that is sometimes considered a type of symbiotic relationship, is parasitism. Parasitism occurs when one organism benefits by harming another. Because it is a close, long-term relationship, it may be considered a symbiotic relationship, yet some scientists believe that the negative effect on one organism puts the interaction into a class by itself. The most important thing to remember is that one organism benefits while the other is harmed. A classic example of parasitism is the mosquito taking blood from animals (including humans). The host is harmed through loss of blood, irritated skin, and sometimes through the transmission of certain diseases such as dengue fever, malaria, or encephalitis. Another example is mistletoe growing as a parasite on mesquite or other desert trees. The mistletoe literally sucks the vital fluids from the host plant.

Competition

An important ecological interaction that is often overlooked, is competition. Competition occurs when two or more species use the same resource, and that resource is in limited supply. An example is the use of a saguaro cavity by several species of birds. Although it may have been excavated by a Gila or other woodpecker, the cavity created in the saguaro is also used by European starlings, house finches, owls, and purple martins. All these birds compete for these prime nest sites in saguaros. Competition most often tends to have a negative effect on both species involved because of the expenditure of energy on competitive aggression.

The plants and animals of the Sonoran Desert ecosystem have developed numerous interrelationships to help them survive in this often harsh environment. Through feeding relationships, symbiotic relationships, parasitism, or competition, there exists a complex web of interrelationships among the organisms that share this ecosystem. The web of connections is complex and dynamic and involves probably every organism in the ecosystem. In fact, the saying "everything is connected" is certainly true for the organisms of the Sonoran Desert.

THE SCIENCE OF CONNECTIONS - *ECOLOGICAL INTERACTIONS*

The activities or relationships that occur between two (or more) different species of organisms are called ecological interactions. They are called ecological interactions because they contribute to the overall dynamic balance of an ecosystem. Ecological interactions can be identified by how the organisms involved are affected--either positively (+), negatively (-), or not affected (0).

Ecological Interaction	Definition	Example
COMPETITION	Two or more organisms using the same resource and that resource is in limited supply (-) (-)	Pocket mice and Harri's antelope ground squirrels both collect and eat the seeds of the palo verde tree.
SYMBIOSIS	Literally means living together. A long term, close relationship between organisms which benefits one or both of the organisms:	
MUTUALISM	A symbiotic relationship in which both organisms benefit (+) (+)	Mutualism: mexican long-nosed bats gather nectar from organ pipe cactus, pollinating the flowers.
COMMENSALISM	A symbiotic relationship in which one organism benefits and the other is unaffected (+) (0)	Commensalism: The creosote woolly gall fly lays its eggs on the stem of creosote bushes. The plant cells mutate to form a leafy, round clump (a gall) which provides a safe place in which the young flies grow while feeding on the gall. The creosote bush is apparently unaffected.
PARASITISM	A relationship in which one organism benefits and the other is harmed (+) (-)	Desert mistletoe attached itself to mesquite trees, sucking moisture and nutrients from the tree.
PREDATOR - PREY INTERACTIONS	The flow of energy through organisms in an ecosystem involving the act of one organism gaining energy by eating another organism. Includes herbivory (+) (-)	Ocotillo produce seeds, harvester ants collect and eat seeds, horned lizards eat harvester ants.

SONORAN DESERT INTERACTION CARD

primary organisms: tarantula - tarantula hawk

tarantula (*Aphonopelma chalcodes*) This large, hairy spider is formidable looking but is actually quite gentle. Tarantulas are nocturnal. Males are more active than females, roaming about on warm summer nights while females remain closer to their burrows. Tarantulas live in silk lined burrows and spin long strands of silk to serve as "trip wires" around the outside of their burrows. The trip wires serve to alert them of passing prey. They have a mild venom and large fangs but their main form of defense is to kick and fling off the tiny hairs from their abdomen. This serves to discourage enemies because the hairs can be very irritating when lodged in the nose or eyes.

tarantula hawk (*Pepsis chrysothemis*) The tarantula hawk (sometimes called pepsid wasp) is a very large, conspicuous wasp with a metallic, blue-black body and large, orange or blue-black wings. This wasp is hard to miss in the Sonoran Desert. The mated females seek out tarantulas, either "teasing" them out of their burrows or going in after them. The tarantula hawk delivers a powerful but not fatal sting to the tarantula, paralyzing it. The helpless tarantula is dragged to a nearby nest site, which is a small hole dug by the tarantula hawk. The tarantula hawk then lays a single egg on the tarantula. The hatched larva slowly devours the paralyzed tarantula while it is still alive. The non-essential tissues are eaten first, keeping the tarantula alive as long as possible. The larva then pupates into an adult tarantula hawk, leaving behind the dead host tarantula.

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SONORAN DESERT INTERACTION CARD

primary organisms: Mexican long-nosed bat - organ pipe cactus

organ pipe cactus (*Stenocereus thurberi*) Organ pipe cactus occur throughout the desert areas of Sonora and Baja California in Mexico. However, in the U.S., they occur almost exclusively in Organ Pipe Cactus National Monument. This cactus has numerous "arms" which reach more than 5 meters high from a common base. Although the delectable fruit is covered with thorns, it is a favorite of many animals, including humans. Organ pipe bloom from May through July. Their large, white flowers open at night, attracting bats and moths, which serve to pollinate the flowers and ensure a new crop of seed-filled fruits.

Mexican long-nosed bat (*Leptonycteris sandbornii*) The Mexican long-nosed bat is a small brownish bat that lives in caves and old mines in desert mountains. It feeds mainly on nectar, pollen, and insects. Like most bats, the long-nosed bat comes out at night to gather food for itself and its young. In the spring and summer when the organ pipe cactus is blooming, the nectar and pollen from that flower becomes one of the bat's primary food sources. In the process of gathering nectar (either by alighting on the cactus or hovering over the blossom), the bat pollinates the organ pipe flower.

SONORAN DESERT INTERACTION CARD

primary organisms: creosotebush - creosote grasshopper

creosotebush (*Larrea tridentata*) The creosotebush is one of the most common plants in the Sonoran Desert. This bush can live in some of the harshest, driest desert conditions. Its leaves are covered with a protective, waxy resin which after a rain, washes off and fills the desert air with a distinctive, pungent odor. This waxy resin serves to help the plant conserve moisture but is also distasteful to many animals. Some insects however, find creosote leaves quite tasty. There are several species of insects which occur only on this plant, including a species of small grasshopper.

creosote grasshopper (*Ligurotettix coquelletti)* Creosote grasshoppers are at their peak of activity when other desert animals are "laying low" and trying to keep cool. During the heat of summer, the male creosote grasshoppers are hanging out in creosotebushes "singing" their little click-like songs in effort to attract mates. The females are attracted to the male's clicky song and flit about the bushes to find males with which to mate. The males are very territorial and will stay in one bush chasing other males away. Creosote grasshoppers feed almost exclusively on creosotebushes and the creosotebush occupied by the male is its primary food source which it readily share with the female.

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SONORAN DESERT INTERACTION CARD

primary organisms: pipevine - pipevine swallowtail butterfly

pipevine (*Aristolochia watsoni*) This small vine is somewhat inconspicuous but not uncommon in the Sonoran Desert. It typically grows among the branches of another desert shrub or tree. The pipevine has somewhat toxic qualities and is reported to have historically been used medicinally, especially as a remedy for snakebite.

pipevine swallowtail butterfly (*Battus philenor*) This glossy, blue-black butterfly is common in city gardens as well as mountain canyons in our desert region. The adult butterfly gathers nectar from several plants including Mexican morning glories. Although attractively colored, the butterfly is distasteful and even poisonous to predators. The butterfly's coloration serves as a warning to would-be predators. The butterfly actually becomes toxic during its larval stage. The caterpillar larvae use the pipevine plant almost exclusively as its food source. The caterpillar feeds on the pipevine and retains the plant's toxin in its body as it becomes an adult. It is this toxin, originally from the pipevine, that renders the adult butterfly safe from predators.

SONORAN DESERT INTERACTION CARD

primary organisms: mesquite - bruchid beetle

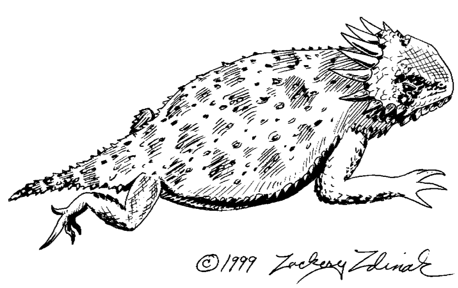
mesquite (*Prosopis sp.*) The mesquite is one of the most common trees in the Sonoran Desert. There are several species of native mesquite including the honey mesquite and the velvet mesquite. Mesquite trees blossom in the spring, their fragrant blooms attracting numerous species of beetles and bees. By summer, the pollinated blossoms have produced an abundance of yellowish bean pods. The bean pods are very protein-rich and are eaten by humans as well as a variety of animals including coyotes, rodents, and insects. The pods remain on the trees until late summer when they drop, often around the time of the summer rains. Mesquite is said to have been one of the most important trees to people in this region and has been used for fuel, food, shelter, tools, and medicine.

bruchid beetle (family Bruchidae) Bruchid beetles are one of the smallest insects to eat mesquite beans but because of their numbers, they can destroy as much as half of the tree's seed crop! The adults of this tiny beetle feed on the tree's pollen and nectar and mate on the flowers. They lay their eggs on the maturing bean pods. The hatched larvae eat their way into pod and feast on the seeds within. After the larvae change into adult beetles, they chew their way out leaving a tiny, but conspicuous hole in the pod.

SONORAN DESERT INTERACTION CARD

primary organisms: regal horned lizard - loggerhead shrike

regal horned lizard (*Phrynosoma solare*) Of the seven species of horned lizards in the U.S., the regal is considered to be the horned lizard most closely associated with the Sonoran Desert. Although it is truly a lizard, it is sometimes called a "horny toad" because of its round body. Ants are the primary food source of the horned lizard. A horned lizard will sit quietly by an ant hole, darting out its sticky tongue to lap up its prey. The horned lizard has the coloring and pattern of the desert soil. However, its camouflage does not always protect it from keen-eyed, avian predators such as hawks, roadrunners, and shrikes. In addition to its protective coloration, its defenses include its wide, spiny head and an ability to squirt blood from its eyes when alarmed. This of course, only serves to startle its enemies, but sometimes allows the lizard to escape.



loggerhead shrike (*Lanius ludovicianus*) The loggerhead shrike is a common but not well known bird of the Sonoran Desert. This bird also occurs across the continent in both the U.S. and Mexico. They are most often seen sitting atop tall trees or on telephone wires. They are a striking bird with a gray body and head and a black eye-line on a white face. The wings and tail are also black. The shrike is often mistaken for a mockingbird but is stockier and more predaceous. Although not a true "bird of prey," shrikes are predators that eat a variety of large insects, small lizards, and sometimes even small birds and mice. They land on their prey and deliver a hard blow from their powerful beak. They are especially known for saving some prey items by impaling them on large thorns or barbed-wire fences. If one ever encounters a skewered horned lizard or grasshopper, it was likely put there by a loggerhead shrike.

SONORAN DESERT INTERACTION CARD

primary organisms: creosotebush - creosote lac insect

creosotebush (*Larrea tridentata)* The creosotebush is one of the most common plants in the Sonoran Desert. Its leaves are covered with a protective, waxy resin which after a rain, washes off and fills the desert air with a distinctive, pungent odor. There are several species of insects which occur only on this plant. In this particular interrelationship, the creosotebush is the host plant for the lac insect.

lac insect (*Tachardiella larrae)* This tiny insect is called a "lac" insect because it sucks the juices of its host plant and produces a lacquer-like substance. The lac is form by a gland on the insect's body which secretes a liquid that soon hardens and covers the body of the insect. Lac insects hang out in groups so their globs of lac all coalesce together, forming larger globs of lac. The globs are a rusty colored, crusty substance with pale goo coming out. The goo is the honeydew, also secreted by the lac insects. Because the lac completely covers the insects, it serves to protect them from predators.

➪ *Bonus Interactive Organism: human* (*Homo sapiens*) The lac secreted by the insects is sometimes collected by humans. Because lac repels water, it can be used to seal baskets to make them waterproof. Years ago, the Tohono O'odham collected the creosote lac to waterproof their baskets. Because each drop of lac is not large and lac insects are not abundant, collecting enough lac for use could take a very long time.

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SONORAN DESERT INTERACTION CARD

primary organisms: prickly pear cactus - cochineal

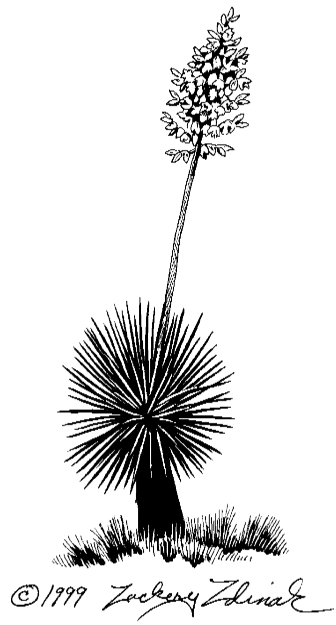
prickly pear cactus (*Opuntia sp*.) The prickly pear cactus is one of the most common and well know cactus of the region. Its fleshy "pads" are usually covered with sharp spines to protect the succulent plant from hungry desert animals. However, some desert animals are able to eat the pads, spines and all. The prickly pear produces a juicy, red fruit that is delectable to many desert dwellers, including humans.

cochineal (*Dactylopius confusus*) This tiny, "scale" insect lives by sucking the juices of the prickly pear cactus. The insect itself is not conspicuous, but the white, waxy substance which it secretes over its body as protection, is very obvious. On prickly pears that have large infestations of cochineal, the pads may look like they're covered with "spitwads." This whitish substance protects the cochineal insect from both predators and the harsh, dry environment. The insect itself however, is apparently immune to most predators because of a substance inside its body which is very distasteful. This substance is a red pigment called anthraquinine.

➪ *Bonus Interactive Organism:* human (*Homo sapiens*) Humans who live in areas where prickly pear grow have long collected and eaten the plant's ripe fruits and young pads (which are called nopalitos and commonly available in most grocery stores). Humans have also discovered the tiny insects living on the pads and found an important use for them. Cochineal means "scarlet-colored" and the cochineal insects have long been collected and used as a dye for both food and textiles. The first known users of cochineal were the Aztecs but the practice quickly spread to Europe. The red from the dye was apparently used by Michelangelo for paint, by the British for their "redcoats," and by the Canadian Mounted Police for their coats. The dye is still collected and used commercially.

SONORAN DESERT INTERACTION CARD

primary organisms: soaptree yucca - yucca moth



soaptree yucca *(Yucca elata)* One of the most common species of yucca in the Sonoran Desert, the soaptree yucca, is so named because its roots have been historically used by the Tohono O'odham (and others) to make soap. Although it looks somewhat like an agave, this spikey plant is actually a member of the lily family. The stiff, pointed leaves are the primary material in Tohono O'odham baskets. In the spring, tall bloom stalks shoot up from the main plant. The stalks are covered with creamy white flowers. Pollinated flowers produce pods which remain on the stalks into the fall.

yucca moth *(Tegeticula sp.)* The yucca moth relies completely on the yucca plant for completion of its life cycle. When adult yucca moths emerge in the spring from their underground cocoons, the flowers of the yucca are just beginning to open. After mating, the pregnant female moth enters a yucca flower, gathers the sticky pollen and forms a ball of pollen. She carries the pollen ball to another yucca flower where she first pierces the ovary wall and lays her egg inside. She next forces the pollen ball into the stigma, fertilizing the yucca ovules. The seeds which form will become the food for her larva. The yucca produces numerous seeds all contained in three-sectioned pods. The pods eventually fall and the larva makes its way underground to form a cocoon and become a moth. Although yucca seeds are the only food for the yucca caterpillar, it does not eat all of the plant's seeds, and the yucca plant does not get pollinated in any other way than by the yucca moth. The moth and the plant are dependent on each other for survival.

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SONORAN DESERT INTERACTION CARD

primary organisms: Gila woodpecker - European starling

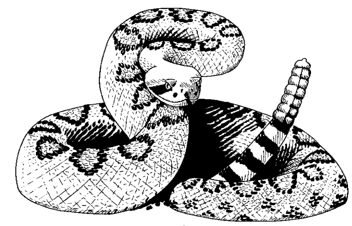
Gila woodpecker (*Melanerpes uropygialis*) The Gila woodpecker is a noisy, conspicuous desert bird. Its loud chatter sounds scolding and sassy. Gila woodpeckers nest in cavities and they excavate most of their nests in saguaro cacti. Gila woodpeckers will usually not use a freshly excavated cavity but will wait a year for it to "heal" and form the hardened lining. Usually they will excavate a fresh nest after their young have fledged. The Gila woodpecker will actively defend its nest cavity both before and during nesting. However, at the beginning of the nesting season, if it arrives at its anticipated nest site too late, another bird may already have established itself at the nest cavity. Other birds using Gila woodpecker cavities include purple martins, owls, house finches, northern flickers, and European starlings.

European starling *(Sturnus vulgaris)* The European starling is a medium-sized, black bird originally from Europe but introduced in New York City in 1890. The starling has been very successful in North America and has spread across the continent. Starlings are considered opportunists, taking advantage of a variety of food and shelter options. They are mainly a cavity nester, and in the Sonoran Desert, they will readily move into nest cavities in saguaro cacti.

➪ *Bonus Interactive Organism:* saguaro (*Carnegiea gigantea*) The saguaro cactus is perhaps the best known plant in the Sonoran Desert. It occurs nowhere else in the world. It may reach heights of up to 40 feet (12 meters) and grow several "arms" which also reach upwards. In the spring, numerous large, white flowers can be seen on the tops of its arms. These flowers provide nectar and pollen for a variety of desert birds and bats. The red fruits are ripe in midsummer and are eaten by birds and mammals and insects. Humans also collect and eat the fruit. The body of the saguaro is thick and heavy. When a hole is carved out of its flesh by a woodpecker, the saguaro is able to form a type of protective scab over the surface of the wound. Such holes become sought-after nesting cavities by numerous other birds.

SONORAN DESERT INTERACTION CARD

primary organisms: round-tailed ground squirrel - western diamondback rattlesnake



round-tailed ground squirrel (*Spermophilus tereticaudus*) This small brownish-tan ground squirrel is a very common inhabitant of the Sonoran Desert. They build underground burrows, tunneling into the desert soil. There may be several small openings to their burrows. When alarmed, they will quickly dart into the nearest opening. This squirrel is a seed eater (as its scientific name implies) but it also eats other plant parts, and insects. They have many predators including hawks, snakes, and coyotes.

western diamondback rattlesnake (*Crotolus atrox*) This rattlesnake is the largest of the western rattlers, reaching over 5 feet in length. This snake feeds on rodents (mice and rats) and other small mammals (ground squirrels and small rabbits). Like other rattlers, the diamondback has a very potent venom which it injects into its prey (or other unwary victim) through its hypodermic-like fangs. When the rattlesnake is disturbed, it coils its body and rattles its tail as a warning. The coiled body is like a spring which helps propel the body forward when striking at a victim. Western diamondbacks are often out during the daytime, warming their bodies. However, they also hunt at night. The rattlesnake's enemies are primarily avian hunters, such as hawks and owls, which are able to avoid being bitten when capturing the rattlesnake from above.

➪ *Bonus Interactive Organism:* red-tailed hawk (*Buteo jamaicensis*) The red-tail is one of the most common hawks throughout the U.S. and northern Mexico. It is a soaring hawk and has broad wings and a wide, fanned tail which help it to soar. The tail is indeed a rusty-red color in adult red-tails. The red-tail hawk is a bird of prey, meaning it belongs to a group of birds especially adapted to hunt and kill other animals. Red-tails primarily eat small mammals (such as rodents, squirrels, and rabbits) and reptiles (snakes and lizards).

✂- -

SONORAN DESERT INTERACTION CARD

primary organisms: cicada - cicada killer

cicada (family Cicadidae) Anyone who has spent a summer in the Sonoran Desert is familiar with the call of the male cicada. Its raspy, high pitched whine coincides with the onset of summer heat. Cicadas spend most of their lives underground as nymphs. There, they suck juices from plant roots. The most common species in the Sonoran Desert, the Apache cicada (*Diceroprocta apache*), stays underground for 3 years before emerging as an adult. Another species spends 13 years underground while another takes 17 years before emerging! After their larval stage in the ground, cicadas emerge and complete one last molt, usually while attached to the base of a tree or building. Their translucent, tan, larval shells can be found where they emerged. The adults live only a short time, primarily among the branches of trees sucking plant juices and mating. The males use their call to attract females. Females lay their eggs on small branches and the hatched larva fall down to the ground to dig in for their underground cycle.

cicada killer (*Sphecius grandis*) The cicada killer is a large, brown and yellow, conspicuous wasp that looks ominous but is generally harmless to humans. After mating, cicada killers seek out cicadas to feed their larvae. The female cicada killer is the one that actually hunts down cicadas, usually by following the calls of the males. She will deliver a powerful sting into the cicada's central nervous system, then carry off the paralyzed insect to her nest, which is a tunnel made in sandy soil (often under sidewalks). She lays an egg on the cicada and seals off that section of tunnel and flies off to repeat the process. The larva hatches to find a still living, fresh food source which it devours before becoming an adult.

SONORAN DESERT INTERACTION CARD

primary organisms: mesquite - desert mistletoe

mesquite (*Prosopis sp.)* The mesquite is one of the most common trees in the Sonoran Desert. There are several species of native mesquite including the honey mesquite and the velvet mesquite. Mesquite trees blossom in the spring, attracting numerous species of insects. By summer, the pollinated blossoms have produced an abundance of yellowish bean pods. Mesquite is said to have been one of the most important trees to people in this region and has been used for fuel, food, shelter, tools, and medicine. During the cooler months, mesquite lose many of their feather-like leaves. Whether bare or leafed-out however, dense clumps of vegetation are often visible among the branches of some trees. These clumps are not mesquite branches but are an entirely different plant, called desert mistletoe, living on the mesquite.

desert mistletoe (*Phoradendron californicum*) Desert mistletoe can be seen growing in several different types of desert trees including paloverde, ironwood, and mesquite. Mistletoe obtains all its moisture and nutrients from the host plant to which it is attached. A tree heavily infested with mistletoe can be fatally damaged, its vital fluids being sapped by the mistletoe. Desert mistletoe produces small, white or reddish berries which turn translucent when "ripe." Some people, including the Tohono O'odham, collect and eat the mistletoe berries. Many animals, especially birds, also eat the mistletoe berries.

➪ *Bonus Interactive Organism:* phainopepla (*Phainopepla nitens*) Although a common Sonoran Desert bird, the phainopepla (pronounced fay-no-pep-la), is unknown to many people. It is a striking bird, with the male having a black body and red eye. Females are gray. Phainopeplas have noticeable crests on their heads, giving them the appearance of a black cardinal. The phainopepla is a member of the flycatcher family and can be seen sitting in the tops of desert trees and flitting up every now and then in pursuit of insects. Another favorite food of this bird is desert mistletoe berries, and the phainopepla will hang out in trees with clumps of mistletoe, eating the berries. The phainopepla is known to spread mistletoe by excreting the seeds as it flies from tree to tree.

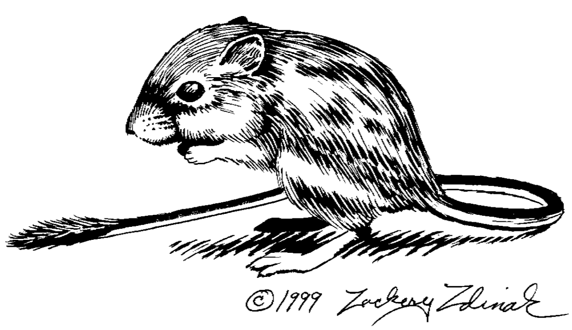
✂- -

SONORAN DESERT INTERACTION CARD

primary organisms: kangaroo rat - Arizona pocket mouse

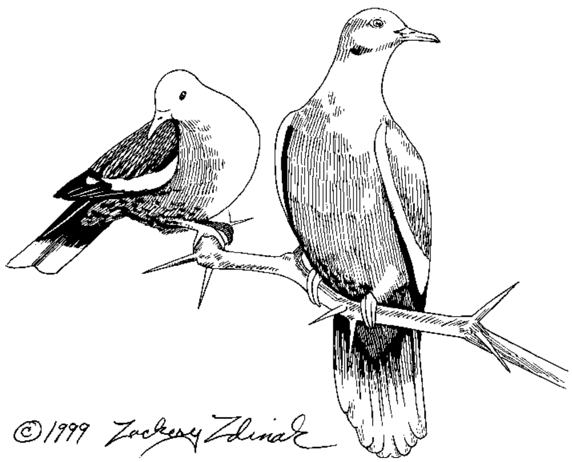
kangaroo rat *(Dipodomys merriami)* This little, nocturnal rodent is so named because of its method of locomotion. Its powerful, long back legs propel it across the desert floor and help it to elude predators. With its long tail and large eyes and ears, this is a distinctive little rodent. Kangaroo rats primarily eat seeds, especially mesquite, paloverde, creosotebush, ocotillo, and grasses.

pocket mouse *(Perognathus amplus)* This tiny, desert mouse is called a pocket mouse because of its ability to carry food in its small, pocket-like cheek pouches. The pocket mouse primarily eat seeds from plants such as mesquite and paloverde. When food becomes scarce, they remain underground and are able to slow their metabolism to conserve energy. They are normally active at night and are very common in the Sonoran Desert. It is said that this mouse will collect a hoard of seeds during summer nights and cache them in small holes. Sometimes they forget where they've buried some of their harvest and inadvertently, they have planted trees!



SONORAN DESERT INTERACTION CARD

primary organisms: saguaro - white-winged dove



saguaro (*Carnegiea gigantea*) The saguaro cactus is perhaps the best known plant in the Sonoran Desert. It occurs nowhere else in the world. It may reach heights of up to 40 feet (12 meters) and grow several "arms" which also reach upwards. In the spring, numerous large, white flowers can be seen on the tops of its arms. These flowers provide nectar and pollen for a variety of desert birds and bats. The red fruits are ripe in midsummer and are eaten by birds and mammals and insects. Humans also collect and eat the fruit.

white-winged dove (*Zenaida asiatica*) White winged doves are summer residents of the northern Sonoran Desert but live year-round in the southern, warmer areas of the desert. They migrate north when the saguaro cactus is blooming to feed on the nectar and pollen. They are major pollinators of the saguaro. White-winged doves also feed on the ripened saguaro fruit, helping to disperse the seeds.

PROFILES OF SONORAN DESERT INTERACTIONS

Directions: Read about your organisms on your Sonoran Desert Interaction Card and answer the questions below.

1. Write the name of the two primary organisms involved in this interaction--include the scientific names. If you have a "bonus interactive organism" include its name:

____

____

2. Write a brief description of the interaction taking place between your two primary organisms:

____

____

3. Complete the table below to describe how each of your primary organisms is affected by this interaction. (If the organism is positively affected, write "+". If the organism is negatively affected, write "-". It the organism is not affected, write "0".)

organism	effects (+) (-) or (0)	type of ecological interaction
1.	organism 1. -	
2.	organism 2. -	

4a. If you have a "Bonus Interactive Organism," describe the role it plays in the lives of the other two organisms. (If you can, name the type of ecological interaction that involves your bonus organism and one of your primary organisms):

____

____

____

4b. If you do not have a "Bonus Interactive Organism" select one of your primary organisms and propose at least one other type of interaction in which that organism is likely to be involved. Include the name of the organism with which it would likely interact. Write about that interaction below. Hint: Consider such things as where your organism obtains energy (food), what might eat it, where it finds shelter, etc.

____

____

____

5. Interview other student pairs in your class to find out about other Sonoran Desert interactions. Complete the table below to describe those interactions.

name of organisms involved	brief description of the interaction	effects (+), (0), or (-)	type of interaction occurring
1. 2.		organism 1 - organism 2 -	
1. 2.		organism 1 - organism 2 -	
1. 2.		organism 1 - organism 2 -	

6. There are two Sonoran Desert Interaction Cards that include humans as the "Bonus Interactive Organism." Locate a student pair that has one of these and interview them about the interaction that involves humans. Describe that interaction below. (Note: if you have humans as a "Bonus Interactive Organism" interview the student pair with the other human interaction.)

7. Humans are involved in numerous interactions with Sonoran Desert plants and animals. Below, list and describe three examples of interactions humans have with different Sonoran Desert organisms (not including the ones already described above). Hint: Consider things we might eat, use as medicine, or use for shelter, art, tools, etc.

MAXED OUT

POPULATION GROWTH AND BIOTIC POTENTIAL

LESSON OVERVIEW

In the previous exercise, students focused on ecological interactions between Sonoran Desert organisms. Interactions among organisms are but one of the contributing factors to an ecosystem's dynamic balance. The growth of plant and animal populations has an enormous effect on ecosystems. This lesson looks at the basics of population growth and gives students an opportunity to consider what populations could do given no limits to their growth. The lesson begins with a brief explanation about the difference between linear and exponential growth. Then, together, the class will calculate the biotic potential of selected Sonoran Desert plants and animals. Real life history data will be provided about the birth rates of several animals for students to use in their calculations. Students will also graph the data to visualize the J-shaped curve depicting exponential growth. Next, small groups of students will work together to calculate the population potential of several generations of a sample organism (suggestions include an ear of corn, a mesquite pod, a bean or pea pod, a grass seed head, etc.). Upon calculating several generations, student will graph their data. This lesson covers only the biotic potential of organisms --how their populations could "explode" without limits to their growth. The activity clearly illustrates that without limits to growth, populations would continue to grow and quickly upset the balance of any ecosystem.

TEACHER PREPARATION

✓ Be sure each student has a copy of the following: Student Activity - Graph: *Dangerous Curves - Biotic Potential Graphs,*and Background Information Fact sheet: *Population Growth, Biotic Potential, and Carrying Capacity*

✓ Review the Background Information Fact sheet: *Population Growth, Biotic Potential, and Carrying Capacity* and assign this as background reading for your students.

✓ Obtain samples of plants which can be used by the students to calculate the organism's biotic potential. Good plants to look for include ears of corn, mesquite pods, other legume (bean) pods (including green beans, pea, mimosa, acacia, paloverde, etc.), grass seed heads (such as foxtail, Bermuda grass, or fountain grass which have numerous seeds per head), dandelions (or other members of the sunflower family which have numerous and obvious seeds), apples or other fruits (or something else that has seeds inside which the students can count), etc.

✓ Have ready, an overhead projector

✓ Have ready, the overhead transparency master: *Curves Ahead - Linear and Exponential Growth*

TEACHING STRATEGY

1. Introduce lesson. Introduce this activity as another example contributing to the dynamic balance of an ecosystem. Whereas in the previous activity investigating ecological interactions, this activity looks at how populations of organisms grow.
2. Demonstrate linear growth. Use the overhead transparency masters to demonstrate

LESSON OBJECTIVES

Upon completion of this activity, students will be able to:

- explain the difference between exponential and linear growth.
- recognize and draw graphs depicting exponential growth and linear growth.
- define the term biotic potential.
- calculate and graph several generations of population growth of an organism given data about its birth rate.

TIME NEEDED

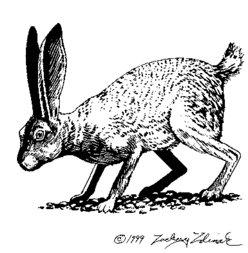
This lesson can be completed in one class period.

MATERIALS NEEDED

- Background Information Fact Sheet: *Population Growth, Biotic Potential, and Carrying Capacity*
- Overhead projector
- Overhead transparency masters: *Curves Ahead - Linear and Exponential Growth*
- Student Activity - Graph: *Dangerous Curves - Biotic Potential Graphs*
- Sample seed plants (see Teacher Preparation)

CURRICULUM TIES

Arizona: 3SC-P5; 4SC-P10



the difference between linear and exponential growth. Linear growth should be presented first to demonstrate the mathematics of linear growth. With assistance from the students, complete the table first then graph the results. Accentuate the straight line when connecting the data points.

3. Demonstrate exponential growth. Exponential growth should next be presented to demonstrate "biotic potential" --the way populations would potentially grow if there were no limits to their growth. Again, complete the table then graph the results. Keys are provided as a guide. Accentuate the J shape of the exponential growth curve.
4. Review and discuss several examples of exponential growth. Additional population data is provided should the class need another example to demonstrate exponential growth. It is important to point out that in calculating animal populations, one must take into account life history information such as sex ratio of the population, birth rate (number of young per litter and per year), age of sexual maturity, and age of mortality. For ease of this lesson, we are making some assumptions about these animals' life histories.
5. Pass out sample organisms and conduct activity. Divide the class into teams of 2 to 4 students, depending on the number of sample organisms you have available for the activity. Pass out the sample organisms to the student teams. Also be sure each student has their copy f the Student Activity - Graph: *Dangerous Curves - Biotic Potential Graphs*. Review the directions and go over any questions the students may have about the activity.
6. Wrap up activity. When students have completed their graphs, review them as a class. Consider the following questions as part of a wrap-up class discussion:

   "Did some plants clearly have greater population potential than others?"
   "What kinds of numbers are more realistic for the amount of fruit, beans, or seeds produced by an individual plant?"
   "Do populations really grow unabated like this?"
   "What kinds of things happen to organisms that keep them from reaching their biotic potential?"
   "How might abiotic factors affect plants' populations?"

EXTENSIONS

Human population potential. Have students calculate human biotic potential. Assume a human female reaches biological maturity at age 14 and reaches menopause at age 50. Assume that one child is born every other year. Assume that half of the offspring are females. Have students calculate 5 generations of population sizes.

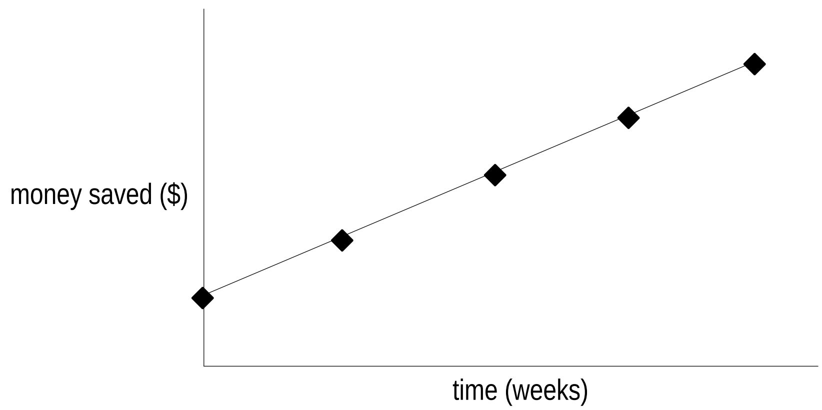
POPULATION GROWTH, BIOTIC POTENTIAL, AND CARRYING CAPACITY

Spring in the Sonoran Desert. Birds are nesting, young cottontail rabbits hop about, and moths flutter at the windows. All around the desert, newborn wildlife are apparent. Another reproductive season becomes evident after the summer rains: young paloverde trees sprout up, new clutches of Gambel's quail dart through the brush, and desert sparrows sing out atop the mesquite trees. Each year, literally millions of new organisms are born, hatch, or sprout up in the desert. If millions of plants and animals are born in the desert each year, why aren't we overrun with wildlife? Why are conservationists always talking about saving biodiversity?

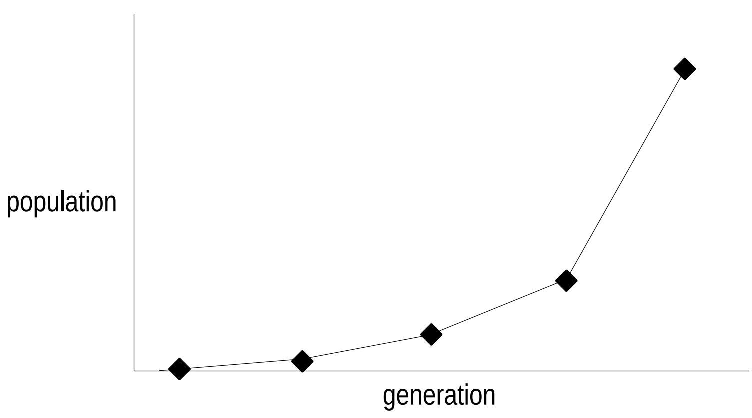
It's true that there are millions of new organisms born each year. Depending upon environmental conditions, a given species may have the potential to far more than double its population. In fact, in a good year, one paloverde tree may produce enough seeds for 80,000 to 100,000 new trees! Just after the summer rains, one can see hundreds of young trees sprouting up under a parent paloverde. How can populations "explode" and why aren't we completely inundated with new paloverde trees each year?

Linear Growth

To answer these questions, one must look at the mathematics of population growth. Populations of living organisms increase somewhat differently from other things. As an example, if a person saved five dollars a week for five weeks, he or she would have twenty-five dollars by the end of five weeks. One could plot this information on a graph and the result would be a straight line showing a steady rate of growth. This is called **linear growth**.



Exponential Growth



Populations of organisms do not exhibit linear growth. Instead, population growth occurs at fixed percentages which, when graphed, resembles a J-shape. This is called **exponential growth**. The rate of growth increases quickly because with each generation, more individuals are capable of reproducing. Because population growth occurs exponentially, organisms that produce rapidly (such as bacteria, house flies, mice, etc.) have the potential for explosive growth.

Biotic Potential

It is easy to see that one plant (or one pair of an organism such as a rabbit) has the potential to produce incomprehensible numbers of offspring. If every offspring of the parent plant (or pair of animals) grew into a reproductive adult, it could be said that that plant or animal had reached its biotic potential. An organism's **biotic potential** is its maximum rate of reproduction given ideal environmental conditions and unlimited resources. Clearly environmental conditions are rarely perfectly ideal for an organism, and resources are rarely, if ever, unlimited. If they were and all populations reached their biotic potential, we would be completely crowded off the planet. Instead, numerous factors exist which limit the growth of populations. Availability of food and water, light, temperature, predation, and an array of other factors keep populations from reaching their biotic potential. These limiting factors are constantly exhibiting pressure on populations to keep them from reaching explosive proportions.

Limiting Factors

Environmental factors which limit populations are typically divided into two types, density independent factors and density dependent factors. **Density independent factors** are those which affect organisms regardless of the size of their population. They exist whether the population increases or not. Density independent factors include climate, weather, and natural disasters. For example, should a flood, freezing temperatures, or even the building of a parking lot occur at a specific place in the desert, all the organisms that live there would be affected, regardless of the size of their population.

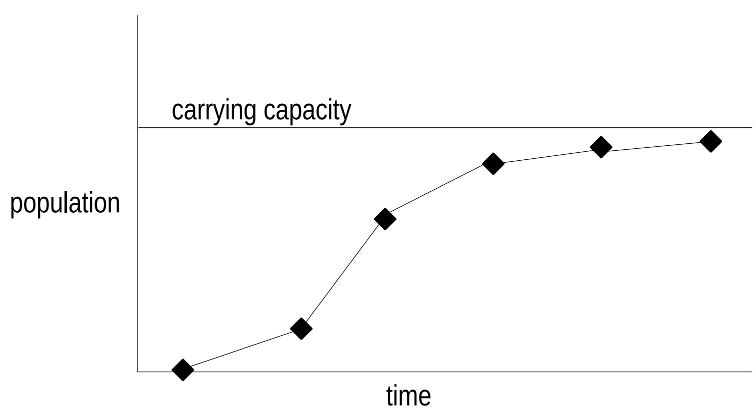
Density dependent factors are those which increasingly affect populations as the population increases. This includes such factors as disease, competition, predation, and parasitism. It is easy to see that as a population gets larger, it becomes susceptible to overcrowding which can lead to increased disease and competition. The resources necessary for the organism's survival (such as food, water, and shelter) must be shared by more and more organisms. More organisms also means that the predators of that organism have more prey and therefore the predator population may increase which leads to more predation. The same may be said of parasitism.

Carrying Capacity

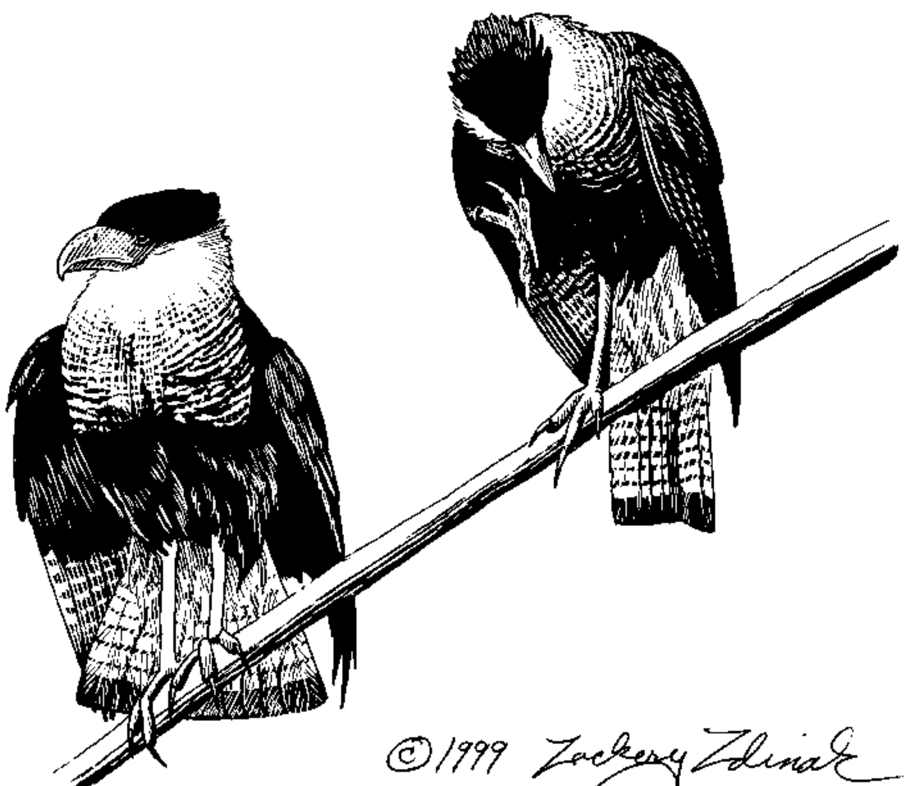
Regardless of the type of environmental factor affecting a population, it is clear that population growth has its limits. Although populations have the potential to grow exponentially, what really happens is that at some point, the population stops growing. This means that as many organisms are dying (the death rate) as are being born (the birth rate). Scientific studies have shown us that instead of a J-shaped curve, population growth curves actually look more like a sideways S. The point at which the population numbers level off is called the carrying capacity for that organism. **Carrying capacity** is the largest number of individuals a given habitat (or environment) can sustainably support. (Sustainably means on a long term ongoing basis.) Although carrying capacity is a point of balance between births and deaths, it is a dynamic equilibrium. It is a measure that can and does change depending upon environmental conditions. As well, a given habitat may be able to support more or less individuals of a species than another habitat.

Carrying capacity is a very important concept in ecology. It defines the dynamic balance of all populations, including humans. It helps scientists better understand what is happening to individual species and entire ecosystems. Knowing how many individuals of a given species a particular habitat can support leads to better wildlife management. It can tell us what kinds of impacts certain activities may have on a particular species and provide clues when species numbers fall for no apparent reason.

Carrying capacity applies not just to wildlife species, but to all living things, including humans. Humans however have the ability to manipulate their environment and bring in resources from outside their immediate habitat. As well, there is yet no



indication that the human population is leveling off. However, ecological principals such as carrying capacity apply to all species. Although we do not yet know the planet's carrying capacity for humans, we do know that it is governed by our use of resources. If we continue to exhaust our resources, there will be a point at which the human population can no longer grow. Perhaps, through scientific foresight and human cooperation, we can find that level of sustainable living without suffering severe population crashes through starvation, disease, or worse. To ensure the future of human kind, we will need to learn to use our resources in a sustainable manner. Living sustainably means using what we need now while ensuring resources for future generations. It could be humankind's greatest legacy.



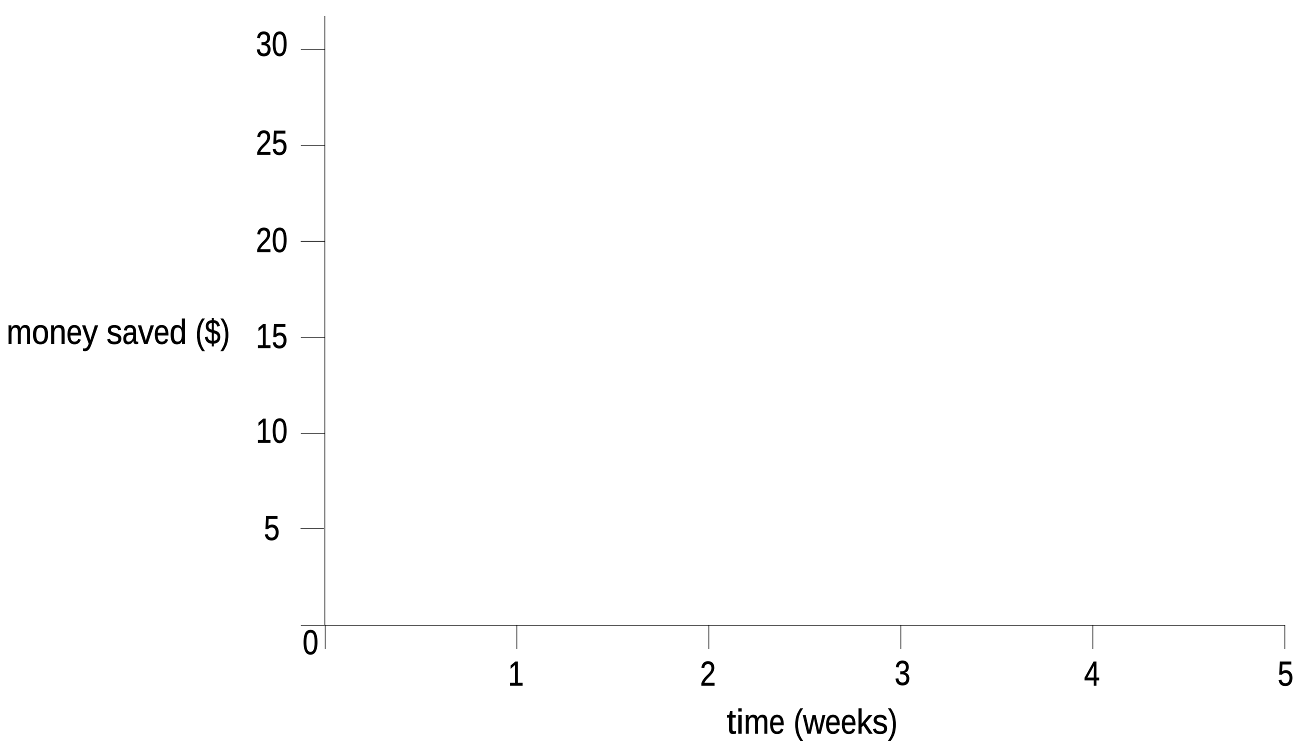
CURVES AHEAD
LINEAR AND EXPONENTIAL GROWTH

Linear Growth - Occurs at a steady rate

Example: You earn $5.00 each week and save it for 5 weeks:

time	money saved
week 1	$5
week 2	
week 3	
week 4	
week 5	

Increase occurs at a steady rate and the growth can be represented by a straight line - called linear growth.



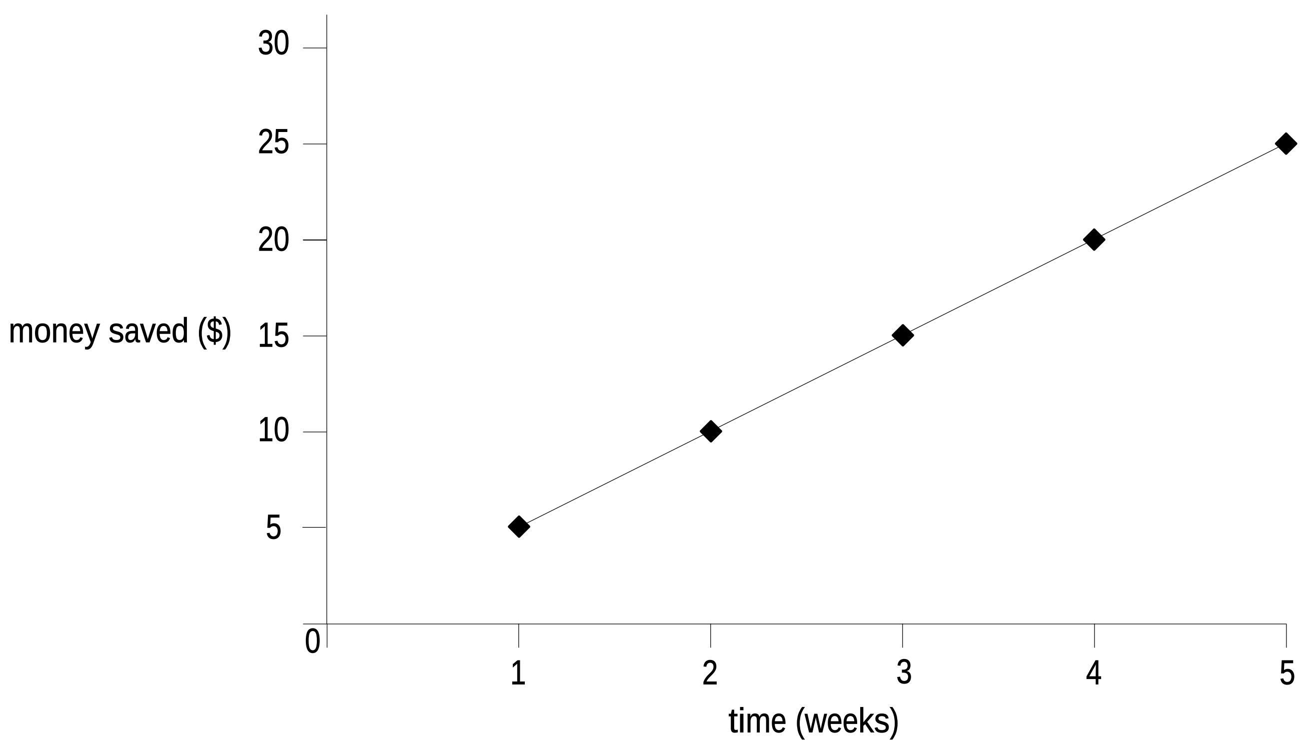
CURVES AHEAD
LINEAR AND EXPONENTIAL GROWTH

Linear Growth - Occurs at a steady rate

Example: You earn $5.00 each week and save it for 5 weeks:

time	money saved
week 1	$5
week 2	$10
week 3	$15
week 4	$20
week 5	$25

Increase occurs at a steady rate and the growth can be represented by a straight line - called linear growth.



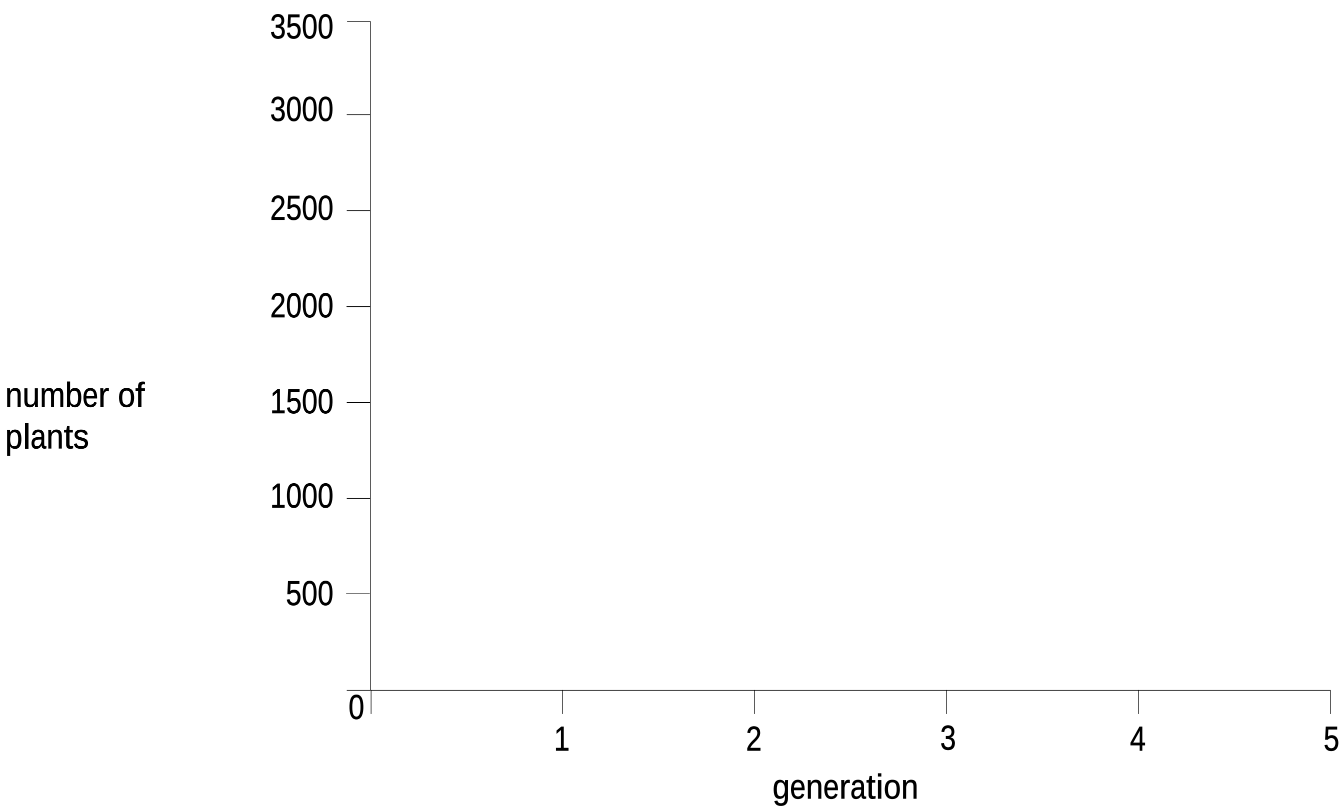
CURVES AHEAD
LINEAR AND EXPONENTIAL GROWTH

Exponential Growth - Occurs when growth occurs at fixed percentage

Populations of living things do not exhibit linear growth, they exhibit exponential growth.

Example 1: How many plants could one flower potentially produce after 5 generations? Assume that the flower produces five seeds and each seed germinates and grows into another plant that produces one flower that also contains five seeds.

generation	number of plants
1	5
2	
3	
4	
5	



CURVES AHEAD
LINEAR AND EXPONENTIAL GROWTH

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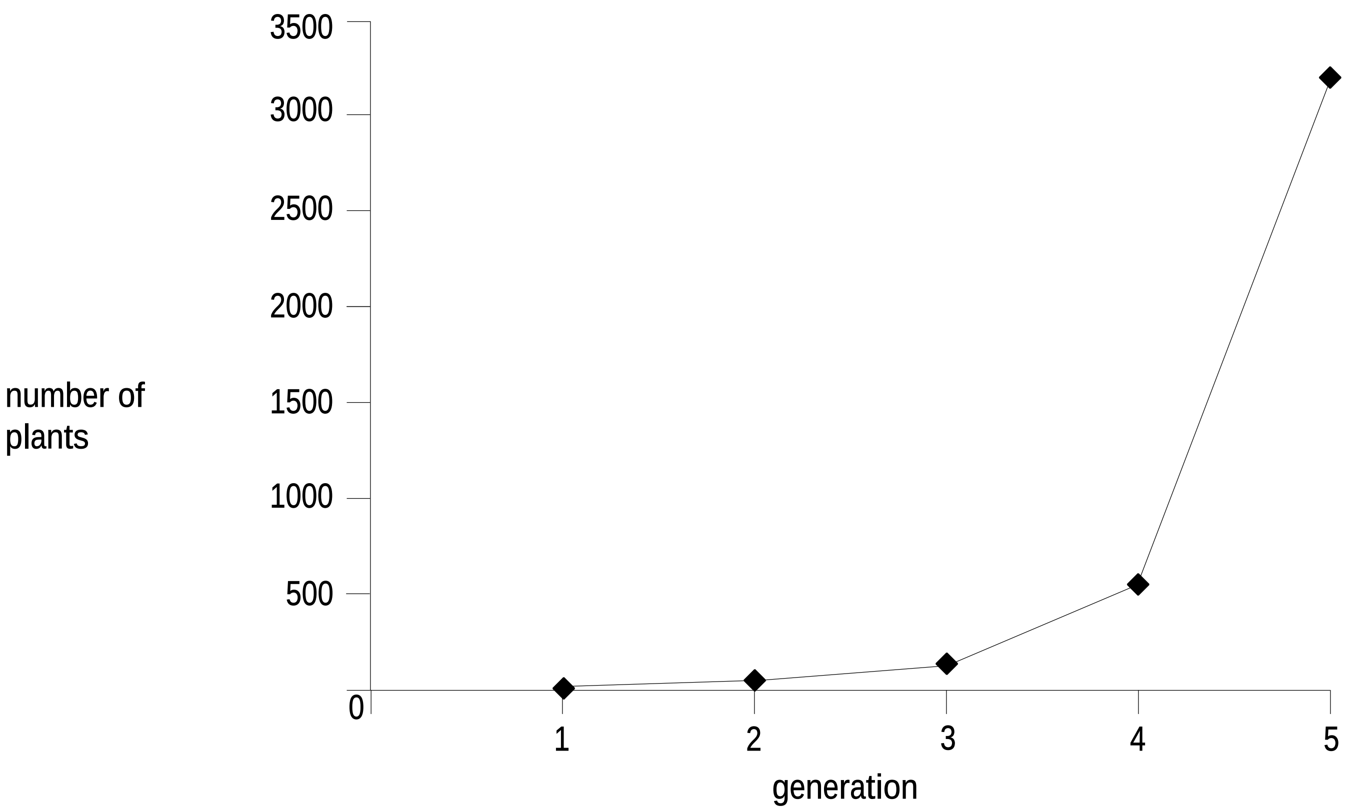
Populations of living things do not exhibit linear growth, they exhibit exponential growth.

Example 1: How many plants could one flower potentially produce after 5 generations? Assume that the flower produces five seeds and each seed germinates and grows into another plant that produces one flower that also contains five seeds.

generation	number of plants
1	5
2	25
3	125
4	625
5	3125



CURVES AHEAD
LINEAR AND EXPONENTIAL GROWTH

Exponential Growth - Occurs when growth occurs at fixed percentage

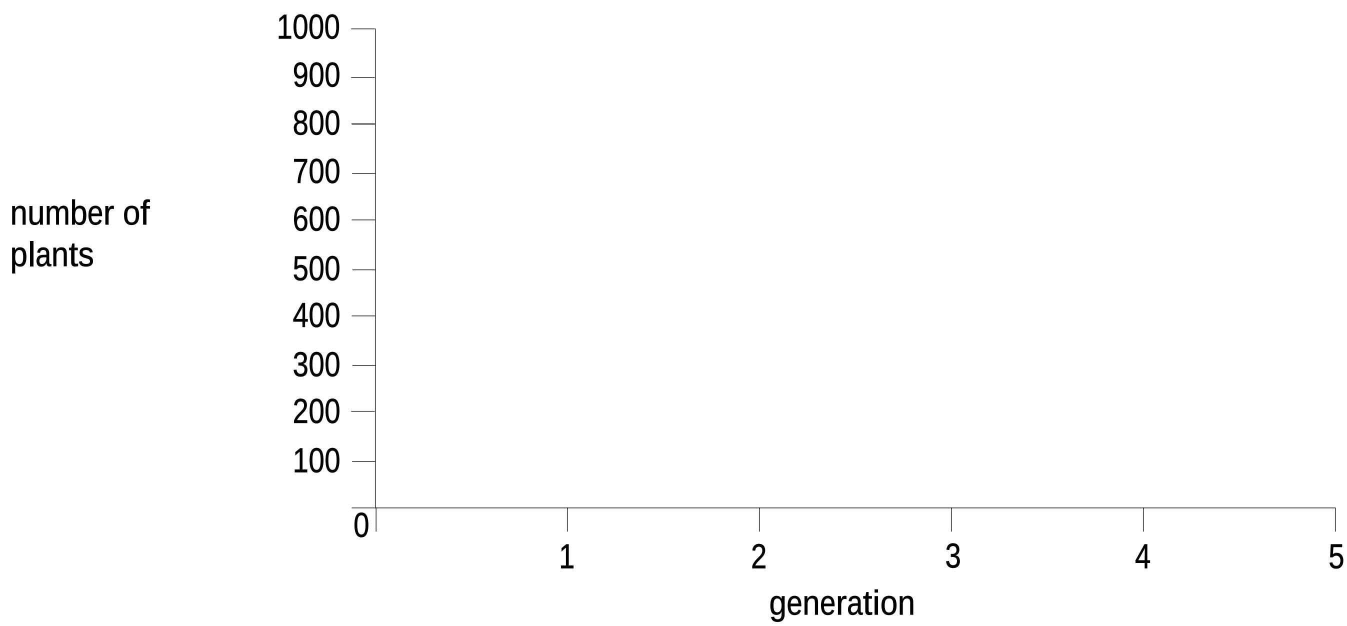
Populations of living things do not exhibit linear growth, they exhibit exponential growth.

Example 2: What would be the population of cottontail rabbits after 6 generations given that they have an average of 4 - 7 young each litter?

- *assume an average number of young per litter = 5*
- *assume we start with 2 rabbits, a male and a female*
- *assume an even sex ratio each generation (½ female and ½ male)*
- *assume they interbreed*

** Note: We use generations because cottontail rabbits may have 3 to 5 litters per year!*

generation	beginning population	number of breeding pairs [half of beginning population]	offspring [number breeding pairs x 5 (ave. young / litter)]	total end population [beginning population + offspring]
1	2	1	5	7
2				
3				
4				
5				



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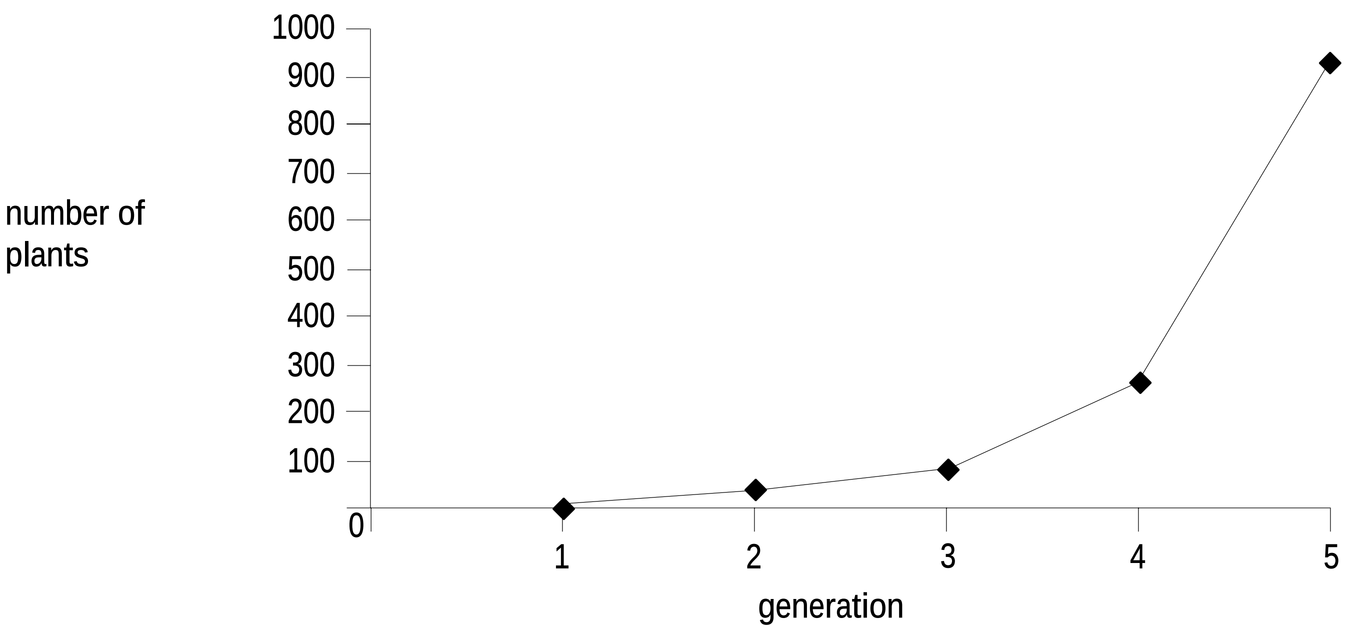
** Note: We use generations because cottontail rabbits may have 3 to 5 litters per year!*

generation	beginning population	number of breeding pairs [half of beginning population]	offspring [number breeding pairs x 5 (ave. young / litter)]	total end population [beginning population + offspring]
1	2	1	5	7
2	7	3	15	22
3	22	11	55	77
4	77	38	190	267
5	267	133	665	932



DANGEROUS CURVES
BIOTIC POTENTIAL GRAPHS

Directions: Generation 1 is your beginning plant (population size equals 1). Count the total number of seeds on your plant (or in your fruit or seed head). Consider that number to be generation 2. For every generation, assume that all seeds germinate and grow to become new plants. Assume (for now) that each new plant produces one seed head, pod, or fruit with the same number of seeds as your original sample. Note: Because these are plants, breeding pairs do not need to be calculated as with animal populations

1. Name of your plant ____

2. Number of seeds on your sample plant ___________________________

3. Using the table provided, calculate the number of plants for the next 5 generations:

Generation	Population Size
1	1
2	
3	
4	
5	
6	

4. Graph your results on the back of this paper (or on a separate sheet of graph paper). Remember to consider the correct scale to take into account the beginning and end populations.

5. As a team, answer the discussion questions below. Choose one person to record your answers but be sure that everyone contributes to the discussion.

a. You know for a fact that your plant produces more than just one seed head, pod, or fruit per generation. How would you take into acount that your plant probably produces at least five times more seed heads, pods, or fruits each generation? Demonstrate your answer by calculating the population for at least three generations considering that each new plant produces 5 seed heads, pods, or fruits instead of one.

b. Propose two things that might happen to your plant to keep it from reaching its biotic potential (lower its population size).

c. How might different abiotic factors affect the population numbers of your plant?

MAXING OUT HAS ITS LIMITS
POPULATION GROWTH AND CARRYING CAPACITY

LESSON OVERVIEW

Once students understand the concept of biotic potential, they begin to realize that most populations do not continue to grow and grow unabated. This activity explores what happens to populations to keep their numbers from "exploding" and overrunning the earth (or any given ecosystem). The lesson begins with an exercise which literally crowds more and more students into a small space (designated in the classroom). The students quickly realize that the space is clearly too small for the entire class to occupy. Using the limited space as an analogy to the planet (or a given space on the planet such as the Sonoran Desert), students will consider what happens to organisms living in a similar, constrained situation. The class will next review and discuss the factors that limit populations such as competition, predation, parasitism, and disease. The concept of carrying capacity will be introduced and graphically depicted with a S-shaped curve for students to visualize how limiting factors affect a population's biotic potential. The class discussion will also focus on ways that different ecological interactions (studied in a previous lesson) affect population growth.

TEACHER PREPARATION

✓ Be sure each student has a copy of the following: Student Activity :Sonoran Desert Population Studies, and Background Information Fact Sheet: *Population Growth, Biotic Potential, and Carrying Capacity*
✓ Review the Background Information Fact Sheet: *Population Growth, Biotic Potential, and Carrying Capacity* and assign this as background reading for your students
✓ Using tape or some other kind of visual reference, designate and mark off increasingly smaller sections of the room. Mark half the room, one quarter of the room, and one eighth the room. (If necessary, you may even mark one sixteenth the room.)
✓ Have ready, an overhead projector
✓ Have ready, the overhead transparence master: *Population Regulation -- Limiting Factors and Carrying Capacity*

TEACHING STRATEGY

1. **Conduct space-reducing activity.** A good way to begin this activity is to give no introductory explanation beyond the fact that you are going to conduct a class experiment. Explain that you are all going to pretend to be a population of desert bighorn sheep:
   - Currently you are living in a space that is large enough and contains all the resources your entire population needs. However, a recent drought has left half of your area unusable for foraging as all of the plants you normally eat have died. Now, the population will have to fit in an area half the size it once was. Point out half the room and indicate that all the students must move to fit in that space.
   - Next say that due to a new shopping mall and parking lot being built in your area you must now all move into an area half the size you are currently in. Point out ¼ of the

LEARNING OBJECTIVES

Students will be able to:
- list and describe at least 3 factors which limit the growth of populations.
- define carrying capacity and draw a graph which depicts a population at its carrying capacity.
- analyze ways in which ecological interactions might affect populations.

TIME NEEDED

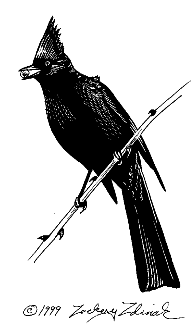
This activity requires one class period plus homework. Review of the same homework may take a small portuion of a second class period.

MATERIALS NEEDED

- Tape or some other type of visual marker to section off portions of the room
- Overhead projector
- Background Information Fact Sheet: *Population Growth, Biotic Potential, and Carrying Capacity*
- Overhead transparency master: *Population Regulation -- Limiting Factors and Carrying Capacity*
- Student Activity: *Sonoran Desert Population Studies*

CURRICULUM TIES

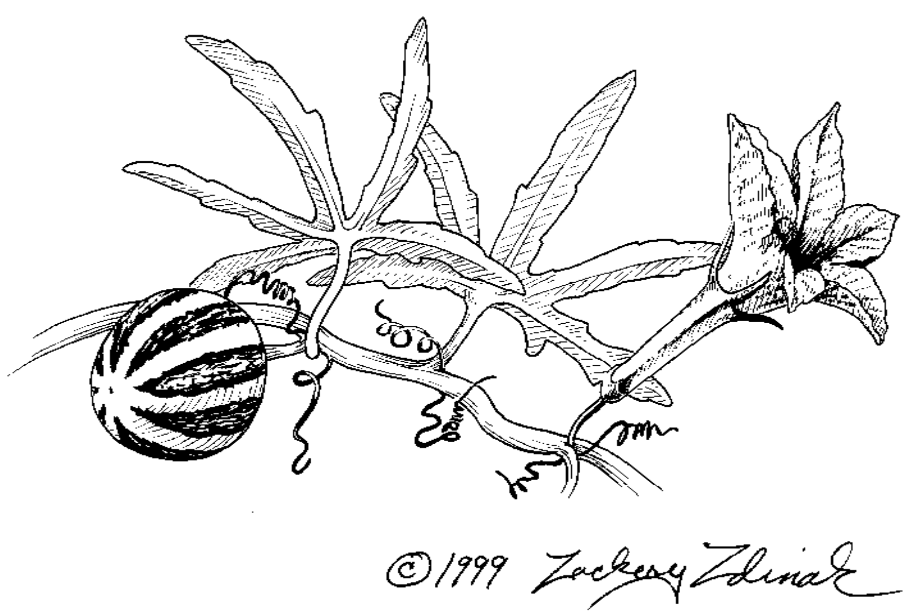
Arizona: 3SC-P5; 4SC-P6; 4SC-P10



room and have students move into that space.

- Next indicate that the student "sheep" must move into an area smaller still due to a housing development built in your area. By this time students should adequately get the picture.

2. **Discuss the implications of the activity.** Have students come up with the point of this activity which is: A given amount of space can only support a certain number of organisms.
3. **Reiterate concept of carrying capacity.** With students still crammed into the small space, ask them how a day in the classroom might be if they all had to stay right where they were. "Would you be able to get any work done all packed together like this?" "Would people feel "stressed-out" at having to rub elbows with fellow students all day?" "What about if they needed a drink or needed to go to the bathroom?" "What do you think happens to wild animals when their space for living gets reduced?" Point out that carrying capacity is not just about how many organisms can live in an area, it is about organisms having enough space and enough resources to adequately meet their needs.
4. **Review exponential growth curves.** Review biotic potential and expontntial growth using some of the previous examples studied by the class. Have a student come up and draw an exponential growth curve on the board. Ask students to consider if this is what really happens in populations -- do populations really grow unabated? Next ask students what keeps populations from reaching their biotic potential.
5. **Discuss the factors that limit population sizes.** Using the overhead transparency master, draw a J-shaped, exponential growth curve in the space provided on the graph. Review the key limiting factors that regulate population growth as listed on the master. As you discuss each, erase some of the top of the growth curve to depict a reduced population. (e.g., "How might disease regulate a population?" "Yes, a disease could cause some of the individuals to die." - erase a bit of the top of the curve to show a decrease in numbers).
6. **Draw an S-shaped curve and discuss carrying capacity.** Continue discussing the population regulation factors until about half of the curve is erased but the curve is still at an obvious incline. Transform the curve into a S shape with the line straightening out at a specific population level. Explain that this is what population growth curves more realistically look like. They reach a dynamic equilibrium level lower than their potential. That population level is called: carrying capacity. Have a student read the definition of carrying capacity as stated on the overhead transparency.
7. **Review worksheets.** Next, explain that students will be analyzing real population numbers of a Sonoran Desert animal. Have students get out their copies of the Student Activity: Sonoran Desert Population Studies. Explain that the population numbers of these animals have been carefully studied to determine the success of their reintroduction into the Sonoran Desert. These are real data.
8. **Conduct worksheet activity.** Give students time to complete their worksheets. It may be necessary for them to complete the exercise as homework.
9. **Review and discuss.** Review the completed worksheets as a class. Conduct a class discussion using the discussion questions as a guide.



POPULATION REGULATION
LIMITING FACTORS AND CARRYING CAPACITY

What regulates the size of populations?

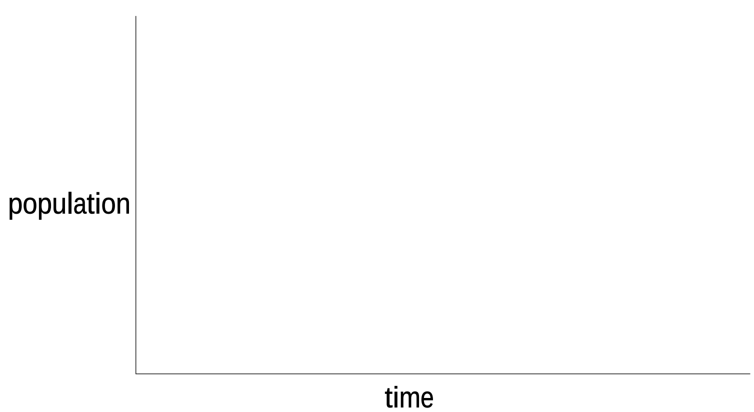
1. DENSITY DEPENDENT FACTORS: factors that increase with an increase in population

Crowding	a population increase can lead to crowding which can lead to increased disease, competition, and parasites
Disease	diseases spread more easily in crowded conditions
Competition	for food, space, water, and shelter
Parasites	parasites often increase when their host populations increase
Predation	predators may increase as a result of increased prey populations

2. DENSITY INDEPENDENT FACTORS: factors that affect populations regardless of size

Environmental factors	temperature, rain, sun, weather
Natural disasters	floods, volcanos, earthquakes
Habitat destruction	human encroachment, pollution, development, invasion of exotic species, etc.

What actually happens?

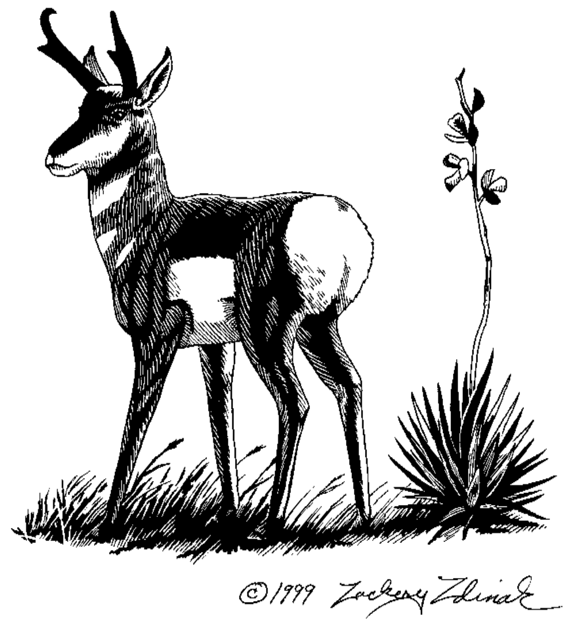


Population growth is depicted by an S shaped curve

Carrying Capacity: The largest number of individuals a habitat can sustainably support.

SONORAN DESERT POPULATION STUDIES

Name ____



The endangered Sonoran pronghorn antelope (*Antilocapra americana sonoriensis*) is the desert subspecies of the pronghorn antelope family. While pronghorn antelope range across prairies of western North America, the Sonoran pronghorn antelope is found exclusively in the Sonoran Desert of Arizona and Mexico. The Sonoran pronghorn became endangered when its habitat, the native grasslands of the Sonoran Desert, was damaged by drought and overgrazing by livestock. Hunting pressures also reduced the population. The Sonoran pronghorn antelope is now a protected species under the Endangered Species Act of the U.S.

In southern Arizona, the grasslands of the Buenos Aires National Wildlife Refuge (prior to its becoming a refuge) were once home to large herds of 200 or more Sonoran pronghorn antelope. In addition to grasslands, the Buenos Aires has cienegas, riparian streams, and desert mountains which provide habitat and travel corridors for a wide variety of wildlife including over 290 species of birds, deer, javelina, coati, mountain lion and even a reported jaguar. While the desert species remained vital, the grassland species of the Buenos Aires (including Sonoran pronghorn and masked bobwhite quail) were extirpated (wiped-out from the region) due primarily to overgrazing and drought over the course of this past century.

In 1985, the Buenos Aires was established as a National Wildlife Refuge. As part of the effort to restore the native grassland ecosystem, the refuge removed grazing and began conducting prescribed burns to mimic natural processes. In 1987, small herd of Sonoran pronghorn antelope was reintroduced to Buenos Aires. The goal of the reintroduction program was to establish a small herd of pronghorn that could sustain their population in the recovering grasslands of the Buenos Aires. In the first group that was released, there were 86 individuals, of which 31 were males and 55 were females. Since that first release, biologists have closely monitored the pronghorn populations and several times each year, they conduct censuses of the pronghorn population. The biologists count the antelope by flying over the entire refuge in a small plane. When they see an animal, they record its location, sex, and whether it is an adult or juvenile. Thirteen years of population data exist as of this writing. As with the reintroduction of any species, the program will be considered a success when it is certain that the population can sustain itself in its habitat. With only 13 years of data, it is difficult to draw conclusions about the pronghorn at the Buenos Aires. However, the data do reveal some interesting information. Below is the actual data from the Buenos Aires population of Sonoran pronghorn antelope. The data was provided by Sally Gall, the wildlife biologist for the refuge.

Population Data of Sonoran Pronghorn Antelope at the Buenos Aires National Wildlife Refuge

Date	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Population	86	37	39	42	46	58	60	62	63	58	64	44	39

Directions: Using the following grid, create a line graph of Sonoran pronghorn antelope populations using the data from the previous page. Remember to label each axis. After you have graphed the data, analyze your graph and answer the questions below.

1. In general, describe your graph (does it go up, down, straight line, etc.).

2. Why do you think the pronghorn antelope population numbers dropped so drastically from 1987 to 1988?

3. What might be some limiting factors for the Sonoran pronghorn antelope at the Buenos Aires?

4. Based on the data, approximately how many antelope do you think the Buenos Aires National Wildlife Refuge can sustainably support? Explain your answer.

HUMAN POPULATION GROWTH
A LOOK AT OUR OWN NUMBERS

LESSON OVERVIEW

While the previous activities looked at population growth of various plants and animals, this activity looks at the growth of human populations in our own Sonoran Desert border region. Actual data about the human populations in various regional communities is provided for students to graph, analyze, and compare. Students will first work in teams to graph their assigned community's data. Each team will post their findings for the rest of the class to use as they next complete a study guide about population growth in the region. The study guide explores issues such as the variation in growth rate among the different communities, affects of growth on the environment and the quality of life, and human carrying capacity of the land. The activity culminates with a discussion about the various issues surrounding population growth in the region.

TEACHER PREPARATION

✓ Be sure each student has a copy of the following: Student Information Page: *Human Population Data from Seven Sonoran Desert Communities,* Student Activity - Graph: *Graphing Regional Human Population Growth*,and Student Activity - Study Guide: *Analyzing Regional Human Population Growth*

TEACHING STRATEGY

1. Review previous population studies and introduce activity. Briefly review with students the class's previous investigations of plant and animal populations and explain that now, the class is going to consider human populations. What do students expect a graph of human population might look like? You might extend this inquiry according to student interest.
2. Divide the class into teams and distribute handouts. There are 7 sets of community population data to be reviewed and graphed. Divide the class into seven teams of students. Assign each team a specific community (Nogales, AZ; Nogales, Son.; Tohono O'odham Nation; Ajo; Sonoyta; Yuma; San Luis Rio Colorado). Have students work in teams to review the data tables, copy their team's data onto their activity sheets, and plot the population data points on their graphs. Remind students to "connect the dots" of their data points. Note: Although students are working in teams, have each complete their own graph of the data.
3. Post completed graphs. Have students post their completed graphs on the classroom wall (or place it on a table) in an area pre-designated for this purpose.
4. Complete study questions. Have students refer to their copies of the Student Activity - Study Guide: *Analyzing Regional Human Population Growth*. Allow students to wander around the room to study the various human population graphs and answer the questions on their forms. (As each student from each team completed a graph, all students should be able to access all the communitys' graphed data.)
5. Review questions and conduct class discussion. When students have completed their study guides, review the questions and answers as a class. You may have students

LEARNING OBJECTIVES

Upon completion of this activity, students will be able to:
- graph human population growth using actual data.
- list and discuss factors which affect the increase and decrease of human populations in the Sonoran Desert border region.
- analyze the potential environmental effects of human population growth.

TIME NEEDED

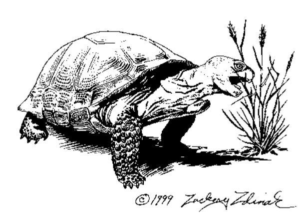
This activity can be completed in one class period.

MATERIALS NEEDED

- Student Information Page: *Human Population Data from Seven Sonoran Desert Communities*
- Student Activity - Graph: *Graphing Regional Human Population Growth*
- Student Activity - Study Guide: *Analyzing Regional Human Population Growth*

CURRICULUM TIES

Arizona: 3SC-P5; 4SC-P10
O'odham: A.7.3; B.7.2



trade and grade each other's work or just review their own. Use the questions as a guide to a class discussion on the subject of population growth in the region.

EXTENSIONS

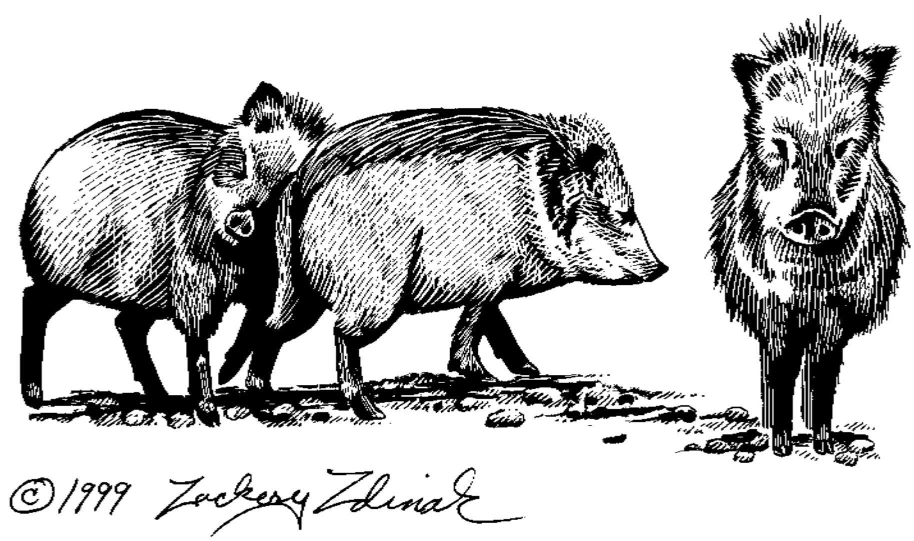
Interviewing Elders. Have students interview elders in their communities to inquire about changes they have seen in their area over time. Instruct students to develop interview questions in advance, carefully considering the kind of information they would like to obtain. Questions to consider could be along the lines of:

"Have you noticed an obvious change in the number of people who live in this area?

"What do you think are positive results of the population growth (or decline) in our community?"

"What do you think are negative results of the population growth (or decline) in our community?"

"What kinds of environmental change have you noticed in this area during your lifetime?"



HUMAN POPULATION DATA FROM SEVEN SONORAN DESERT COMMUNITIES

YEAR	NOGALES, ARIZONA	NOGALES, SONORA	TOHONO O'ODHAM NATION	AJO, ARIZONA	SONOYTA, SONORA	YUMA, ARIZONA	SAN LUIS RIO COLORADO, SONORA
1870						1,144	
1880						1,200	
1890	1,174					1,773	
1900	1,761	2,738				1,519	
1910	3,514	3,177			248	2,914	
1920	5,199	13,445		2,336	483	4,237	175
1930	6,006	14,061		4,571	616	4,892	910
1940	5,135	13,866	5,000		826	5,325	558
1950	6,153	24,478		5,817	1,266	9,145	4,079
1960	7,286	37,657		7,049	1,925	23,974	28,545
1970	8,946	52,108		5,881	2,463	29,007	49,990
1980	15,683	65,603	15,150	5,189	5,430	42,481	76,684
1990	19,489	105,873	18,730	2,919	7,944	56,966	95,461
2000	21,565	131,578	23,800	5,492	7,993	69,055	115,596

GRAPHING REGIONAL HUMAN POPULATION GROWTH

Directions: On the grid below, plot the population of your community. The x axis should be time and y axis should be population. Use a scale that allows you to use as much of the grid as possible. Connect your data points to create a line graph. Label your axes and title your graph. When you are finished, answer the questions on your study guide: Analyzing Regional Human Population Growth.

Title: ____

ANALYZING REGIONAL HUMAN POPULATION GROWTH

Directions: After you have completed your graph as a team, answer the questions below. Part 1 has questions about your assigned community. After you have completed the questions in Part 1, you will need to post your graph (in an area designated by your teacher) for other students to see. To answer the questions in Part 2, you will need to refer to graphs of all of the communities (completed and posted by other teams in your class).

Part 1- Your Assigned Community (information from your team's completed graph)

1. What is the name of your community? ______________________________

2. Describe the type of growth your community has experienced during the last century:______________________

____

3. In what year was your community's population at its smallest? ________________ What was its lowest population?______________________

Part 2 - All Our Border Communities (information from all 7 graphs completed and displayed by the entire class)

4. Which community has the greatest current population? ______________________________

5. Which community has the smallest current population? ______________________________

6. Which community had an increase in population, a definite peak, and then an obvious decrease?
____

7. What might have been the cause for the population decrease in the community referred to above?
____

____

8. Which communities tend to have greater populations, those north of the border (U.S.) or those south of the border (Mexico)? ______________________________

9. What is the population of Nogales, Arizona? ____________________ What is the population of Nogales, Sonora? ____________________

10. Which of these two communities seem to be experiencing the greatest amount of growth?

____

11. What might be a reason for the greater growth mentioned above? ____________________________

____

____

12. What might be some of the environmental problems caused by the tremendous growth exhibited by some of our border communities? Explain your answer.

____

____

____

____

____

13. What might be some limiting factors for human population growth? ___________________________

____

____

____

____

STUDENT EVALUATION

Name____________________ Class ____________________

Fill in the blank - *Write the the correct term in the space provided:*

Special interrelationships between two or more species are called ecological *1.*____________________. When two or more species are involved in a close, long term relationship the interaction is called a *2.*____________________ relationship. When both species benefit from an interaction, it is called *3.*____________________. When one species benefits while the other appears unaffected the relationship is called *4.*____________________. *5.*____________________ occurs when one organism benefits by harming another. A different type of interrelationship is called *6.*____________________, which occurs when two or more species use the same respurce and that resource is in limited supply.

Answer the following questions

7. Describe or draw a food chain involving at least three Sonoran Desert organisms (including plants and animals).

8. Describe an ecological interaction that actually takes place between two or more Sonoran Desert organisms. Be sure to name the organism and state the kind of interaction that occurs between them.

____
____
____
____
____

9. Plot the following data on the graph. Connect the data points.

10. This is an example of what type of growth?

DAY	MONEY SAVED
1	$5
2	$10
3	$15
4	$20
5	$25

____

11. Populations of living things exhibit what type of growth? ____________________. This type of growth is depicted by a ____________________ shaped curve.

Matching - Write the letter of the correct term at right for each definition listed below (there is only one correct answer per question):

12. _____ The maximum rate of reproduction given ideal environmental conditions.

13. _____ Growth that occurs at fixed percentages depicted by a J shaped curve.

14. _____ Factors that affect organisms regardless of the size of their population.

15. _____ Growth occurring at a steady rate depicted by a straight line.

16. _____ Factors that increasingly affect populations as the population increases.

17. _____ The largest number of individuals an environment can sustainably support.

a. linear

b. carrying capacity

c. density dependent

d. biotic potential

e. interaction

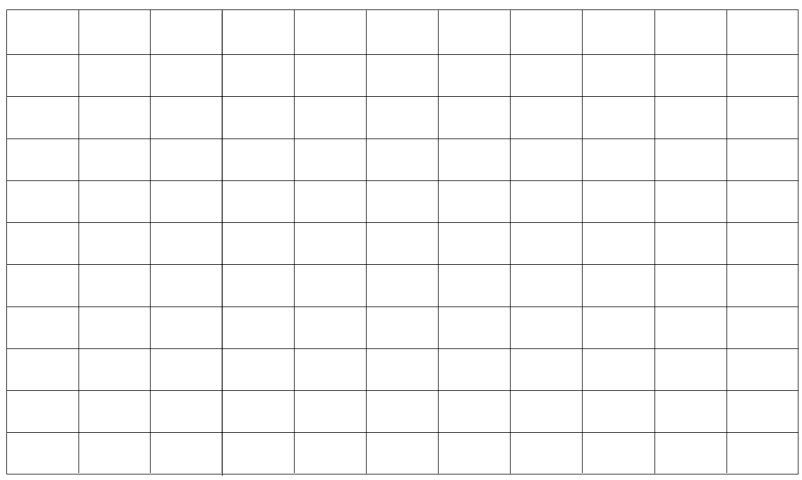
f. density independent

g. exponential

Graph problem -

18. Let's suppose two pairs of rabbits were introduced into a suitable habitat. The population numbers were monitored over time and the following table presents the data. Plot the population data on the grid and answer the questions. Remember to label your axes and connect the data points.

GENERATION	POPULATION
1	4
2	11
3	26
4	52
5	109
6	77
7	85
8	80
9	84
10	82



19. On your graph above, draw a dashed line where the population appears to be at carrying capacity.

20. At what generation does it appear that the population size exceeds the carrying capacity of the habitat? Explain.

____

____

____

____

List five factors that might limit population growth of a species:

21. ____________________ 22. ____________________ 23. ____________________

24. ____________________ 25. ____________________