STUDENT GUIDE

Grizzly Bear Biology

CONCEPTS + ACTIVITIES

Grizzly Bear Conservation Strategy

British Columbia

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STUDENT GUIDE

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The fate of bears in many areas of the world will be decided in the next 10-20 years. The future of several species is in serious doubt. The elimination of bears from 50-75 percent of their historic range has already occurred and the remaining range will decrease unless serious efforts are focused on bear conservation.

Dr. Chris Servheen, biologist

(1990 Report on the Status of Bears)

How do these adaptations function?

1. Ability to stand upright on hind legs
2. Long claws
3. Long muzzle
4. Massive shoulder muscle
5. Massive forearm muscles

Illustration of 2-year old grizzly bears.

Introduction

What is a Grizzly?

What do you know about the grizzly bear? Is it a ruthless killer that stalks people through the wilderness, watching patiently for the moment when it can attack and devour its prey? Is it soft and cuddly and simple like the teddy bear found on so many pillows?

One thing is for certain—the grizzly is well-known but not necessarily well-understood. Almost everyone has a personal grizzly story, or knows someone who does. But the grizzly remains shrouded in mystique and misconception.

Ursus arctos, the grizzly or brown bear, is a difficult **species** to study. It is secretive and it leads a complicated life. It needs a lot of habitat and it needs to be free from temptations such as garbage dumps often plunked by humans on its wilderness doorstep.

In many ways, the grizzly has human-like attributes. It can stand up tall on its hind legs. Females will nurture and guard their offspring at almost any cost. In its wilderness home it is free; the top-level (omnivorous) predator. It is a symbol of the wilderness, and rightly so, for biologists know that to save the grizzly will safeguard the survival of most animal species that share its wilderness home.

But to save the grizzly, we must understand it. We must understand its needs and its **adaptations** and its evolutionary history. For a good start to see what you know about the grizzly, examine the drawings on page 2 at left, and try to determine the usefulness of each of the numbered adaptations. Why does a grizzly have such long claws? What is the purpose of the hump on the back? What about all of the other adaptations indicated in the diagram?

ACTIVITY 1

Bears over Time

Scientists have always strived to put order into everything they do. Several hundred years ago, the science of taxonomy—the business of assigning a technical name to every living creature—arose. Bears, and all other mammals, were assigned their scientific names based primarily on characteristics of their skeletons, as well as certain behavioural traits they shared with presumably closely related species.

Biologists use taxonomy to answer many questions about the relationship of one organism to another. For example, biologists want to know how a polar bear is related to other bears such as the black bear or the grizzly bear; or how a sun bear is related to any of the other bears. Answers to these questions help us understand how these species evolved and how they are suited to their environments, and what we might do to help them survive as species.

In this activity you will explore the relationships among various bear species based on their evolutionary history. This study is called **phylogeny**. If two species evolved from the same ancestor species, then a good phylogeny should put them together as closely-related species – even if they don't look alike. A phylogeny is shown graphically by a phylogenetic tree, where the trunk, branches and stems represent direct lines of evolutionary descent – one species to another.

We use a similar process to show the relationships of individual humans to one another—a process called genealogy. A genealogy shows relationships among individual people according to how they have descended from their ancestors.

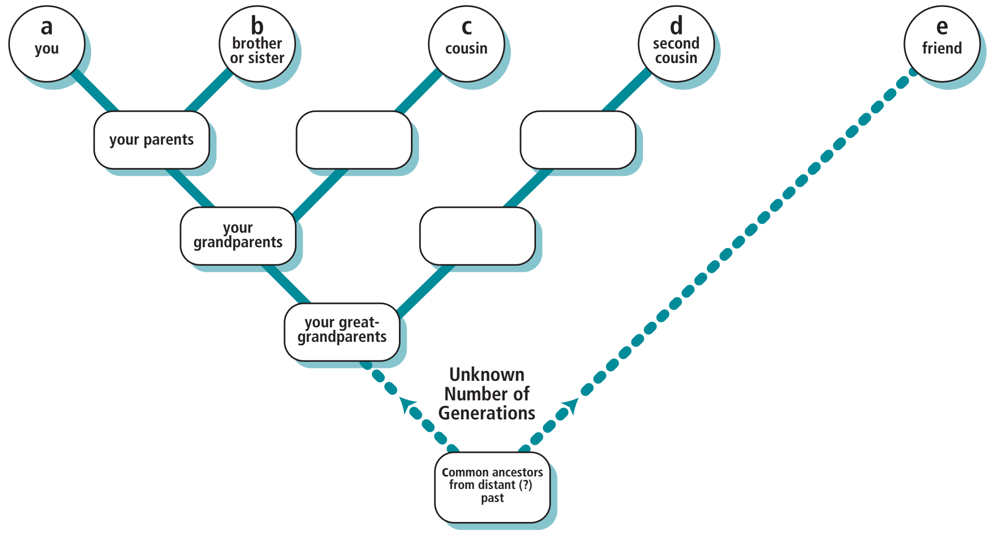
For example, imagine a collection of the following five people:

- **a** you,
- **b** your brother or sister,
- **c** a first cousin (with the same grandparents as you),
- **d** a second cousin (with the same great-grandparents as you), and
- **e** a friend to whom you are apparently not related (at least, in the last three or four generations you have no common ancestors).

Mystery of the Giant Panda

For many decades scientists argued about whether the giant panda from China is a bear or a type of raccoon. The giant panda appeared to share many characteristics with the red panda, a large species of raccoon found in Asia, and the giant panda has some characteristics that are quite un-bear-like, such as its almost exclusive diet of bamboo (no bear species has such a restricted diet) and an apparent extra 'thumb' for holding and manipulating its bamboo food. So is the giant panda a bear or raccoon?...Read on to solve the mystery of the giant panda.

A genealogical tree shows the relationships of these five people and part of their ancestry:



QUESTIONS

Refer to the genealogical tree above to answer the following questions:

1 What common ancestor(s) is shared by the two most closely related individuals?

2 What common ancestor(s) is shared by you (**a**) and a second cousin(**d**)?

3 What is the common ancestor(s) for you (**a**) and your friend (**e**)?

4 How is it possible that you are related to every other human alive today?

Genealogy, Phylogeny

A genealogy reveals the ancestry of the individual; a phylogeny reveals the ancestry of the species. Thus, a phylogeny is a study of evolutionary history. All living things have both a genealogy and a phylogeny.

Creating a Phylogenetic Tree: Solving a Mystery

Phylogenies of species are similar to genealogies of people—they show how species are related by tracing back lineages of descent from **common ancestors**. Of course, there is no written record to show how species evolved over time—so phylogenies must be determined by careful scientific sleuthing. In fact, the evolution of any species is like a fascinating series of mysteries that took place in the past. The following kinds of evidence are used to reveal these mysteries:

- **fossil evidence** Many organisms died in ancient times leaving body parts such as bones or shells that form fossils. Fossils are key evidence to reveal evolutionary history of groups such as the dinosaurs or mammals. New fossils are frequently discovered. Some fossils reveal much about the original organism when it was alive. Even fragments or portions of fossil skeletons can be used by an expert to determine what the animal looked like and how it lived. Teeth tell about what it ate, leg bones tell about how it walked, ran or climbed, appendage structure tells about holding or walking habits, and so forth.

- **comparative anatomy of extant animals** (those alive today) We can compare anatomy of two or more animals (or other organisms), their organs, muscles and other body parts. Closely related species should tend to have close similarities in these body parts, and they should function similarly. Bones are especially useful because they allow us to compare living and fossil species. Researchers can compare the anatomy of animals at different stages in their life-cycles, an approach that has provided many insights into the evolution of invertebrates.
- **chromosomes and gene structure** Closely related species should have very similar genes and chromosomes. Examining chromosome shapes and number can help to show species relationships.
- **molecular studies of DNA, RNA, proteins** Two closely related species should have very similar genes (DNA). By comparing sequences of the 'DNA letters' (nucleotide bases) on these genes, researchers can determine how similar the genetic code of one species is to another. This can reveal how long different species evolved from their common ancestors.

  Also, since genes code for proteins and RNA, we can use the sequences of subunits on these molecules as 'molecular clocks' to determine how far back two different species diverged from a common ancestor. See sidebar: Nature's Ticking Timepieces.

YOUR TASK

Create a Phylogenetic Tree for Bears

Table 1 describes the 8 different species of bears alive today. Table 2 lists 10 species of extinct bears known from the fossil record. How are all these bears related?

Read through the following pieces of evidence and then draw a phylogenetic tree—a 'best picture'—that explains the mysteries of bear evolution for the 18 species of bears in Table 1 and Table 2.

- **fossil evidence and comparative anatomy**
  See Table 1 and Table 2.
- **chromosomes and gene structure**
  - — the giant panda has 42 chromosomes (2N = 42),
  - — the spectacled bear has 54 chromosomes (2N = 54)
  - — the grizzly, black, Asian black, sun, sloth, and polar bears all have 74 chromosomes (2N = 74),

Nature's Ticking Timepieces

If every organism contained a clock inside its body tracking its evolution, we might be able to consult that clock to find out when a species began. Amazingly, biologists have recently discovered that some molecules in the cell such as types of DNA and RNA can be used as crude molecular clocks because they change naturally over time as a result of mutations. By carefully comparing molecules from two different species, biologists can learn approximately how much time has elapsed since the phylogenetic lines of each species separated.

- **molecular studies, DNA, RNA, proteins**

a One DNA study found the following:

— pandas are an ancient lineage of bears, splitting from other bears about 20 million years ago

— spectacled bears are on a distinct line of bears that probably diverged about 15 million years ago

— brown bears (grizzly), black bears, sloth bears, and sun bears are closely related species that diverged about 3 – 5 m.y.b.p. (million years before present)(Polar bears and Asian black bears were not sampled in this study).

b One molecular study using proteins found the following:

— pandas are more closely related to bears than to the red panda or the raccoons

— the ancestor to the panda diverged from the ursid line of bear evolution about 18—22 m.y.b.p.

— the ancestor to the spectacled bear diverged from the ursid line of bear evolution about 11—15 m.y.b.p.

— the remaining six modern bears (the ursid line) are all closely related and diverged from the ancestral stock less than 5 million years ago.

— polar bears are most closely related to grizzly bears and they evolved from the grizzly ancestors most recently (less than 1 million years ago).

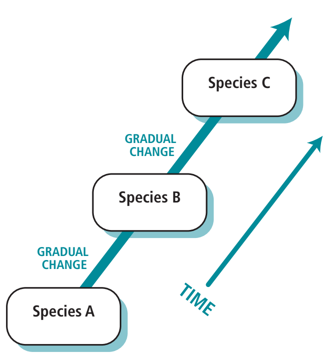
c Three different studies of DNA in mitochondria of North American bears found:

— brown (grizzly) and polar bears are very closely related

— black bears probably diverged from the grizzly/polar bear line of evolution about 3.8 m.y.b.p.

Gradual phyletic change

Gradual phyletic change is a model of evolution in which new species evolve from existing species gradually over long periods of time.



Punctuated equilibrium

Punctuated equilibrium is a model of evolution involving long periods of relatively little change punctuated by short periods where new species appear relatively rapidly.

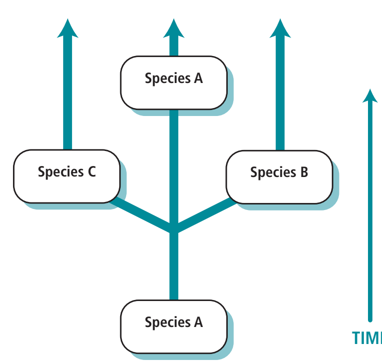


Table 1: Modern Bears and Fossil/Anatomical Evidence About Their Evolution

Name and Scientific Name	Short Summary of Evidence
brown (grizzly) bear *Ursus arctos*	Fossils indicate this species evolved more than a million years ago in Europe, probably from the Etruscan bear. It only migrated to North America during the recent ice ages, probably sometime between 180,000 and 30,000 years ago. Later, it ranged across North America, Asia and Europe.
black bear *Ursus americanus*	Fossils indicate this bear species probably evolved from the Etruscan bear or Asian black bear, in Asia or Europe. It migrated to North America perhaps a million years ago, and is now found only on this continent.
Asian black bear (moon bear) *Ursus thibetanus?* or *Selenarctos thibetanus?*	Found throughout much of Asia including Japan, this species is threatened over its entire range. It is very similar anatomically to the Etruscan bear and is a close living relative to the black bear of North America. The genus name *Selenarctos* is used by many biologists.
sloth bear *Ursus ursinus?* or *Melursus ursinus?*	Found in Sri Lanka, India and western Asia, this bear is thought to number about 7,000 to 10,000. Fossil evidence is very scant. Anatomical evidence was thought to support a separate genus, *Melursus,* but recent evidence suggests it may be directly descended from an *Ursus* ancestor.
Malay sun bear *Ursus malayanus?* or *Helarctos malayanus?*	The smallest living species of bear, this bear, like other tropical bears has left little fossil evidence. Found in the forests of Southeast Asia, Java, Borneo and Malaysia, it is a red-listed endangered species. This species may warrant a separate genus name, *Helarctos*, but there is also evidence to suggest a close tie to the *Ursus* line.
polar bear *Ursus maritimus*	Fossils of this species are extremely rare. The oldest fossils are about 20,000 years old, indicating it evolved very recently in the Arctic regions. Anatomically, the polar bear is more similar to the brown (grizzly) bear than to any other bear species.
panda bear *Ailuropoda melanoleuca*	Found only in isolated pocket populations in China, this bear is very specialized, feeding on bamboo and the occasional small rodent. It is anatomically distinct from any of the other living bear species, and its feeding specialization is distinct.
spectacled bear *Tremarctos ornatus*	This bear species is found only in South America. Fossil evidence is scant. Anatomically, it's bone structure indicates a close relationship to extinct species such as the short-faced bears and the Florida cave bear.

Table 2: Some Extinct Bears and Evidence About Their Evolution

Name and Scientific Name	Short Summary of Evidence
Cephalogale	A small carnivore (raccoon-sized) that lived around 38–25 million years ago. It had dog-like and bear-like features, and is considered one of the earliest bears.
Ursavus elemensis	Fossils indicate this small bear species lived about 20–9 million years ago, and that it eventually evolved directly into the *Ursus* line of bear evolution. This bear type probably also gave rise to another branch of bear evolution – the line leading to the New World short-faced and spectacled bears.
Agriarctos	Lived about 25–13 million years ago. Its bone structure indicates it may have been the direct ancestor to the panda bear.
Plionarctos	Lived about 10–8 million years ago. Its bone structure indicates it was an ancestor to bears of the genera, *Arctodus* and *Tremarctos.*
Auvergne bear *Ursus minimus*	Lived in Europe about 7–5 million years ago. Fossils indicate it was a small bear resembling the black bear with *Ursus* characteristics.
Etruscan bear *Ursus etruscus*	This bear probably evolved from the Auvergne bear. Early fossils (5 million years old) show that it was small, but later fossils show that it gradually transformed to a bear about the size of a brown bear. In anatomical structure, it was most similar to the modern black bear and Asian black bear.
European cave bear *Ursus spelaeus*	Thousands of fossils of this species have been found in European caves and some caves have smooth walls from the passage of bears over the millennia. Fossil teeth indicate it was an omnivore, with vegetation as the main diet. It evolved about 2 million years ago. It is likely that humans played a major role in the extinction of this bear about 11,000 years ago. It has distinct anatomical characteristics of the Ursus line.
lesser short-faced bear *Arctodus pristinus*	This bear lived in North America starting about 1 million years ago. Fossil bones indicate it was related to the giant short-faced bear, and it may have been its immediate ancestor.
giant short-faced bear *Arctodus simus*	This bear species evolved 2 million years ago and became extinct only about 12,000 years ago. It was the largest bear and the largest land mammal carnivore ever to live, weighing as much as a small car and standing to almost 2 metres at the shoulder. Its bone structure indicates it was a fierce predator that evolved along the same evolutionary line as the spectacled bear and Florida cave bear. Some biologists believe that *Arctodus simus* preyed on the early human settlers in North America.
Florida cave bear *Tremarctos floridanus*	This bear species became extinct less than 8,000 years ago. The tooth structure of fossils from Florida indicates it may have fed exclusively on plants. It was similar to the modern spectacled bear of South America, which is a distinct line of evolution from the other modern bears as revealed by anatomical studies.

QUESTIONS

Refer to your own phylogenetic tree for bear species to answer the questions below:

5 Which species is a common ancestor to all modern bear species?

6 Which species is a common ancestor to all modern species with the genus *Ursus*?

7 Which species of modern bear would be considered 'most primitive'? Is this bear more closely related to other carnivore groups than are the other modern bear species?

8 Which portions of the evolution of bears indicate gradual **phyletic change** (See the sidebar "Gradual Phyletic Change and Punctuated Equilibrium")?

9 Which portion of the phylogeny indicates **adaptive radiation** – diversification into a number of different ecological roles? Could this be considered **punctuated equilibrium** (See the sidebars "Gradual Phyletic Change and Punctuated Equilibrium")?

ACTIVITY 2 The Making of a Species:

The Polar Bear

"How does a new species get started?" This is one of the most fundamental questions of biology. In this activity, the polar bear and grizzly become a focus to examine the origin of a new species.

The great naturalist, Charles Darwin, began to develop hypotheses about the origin of species in the 1830s. In the following 20 years he systematically observed and studied nature before publishing his 1859 book, *The Origin of Species by Means of Natural Selection*. Darwin's ideas revolutionized our understanding of the world of living things, and even though he was never able to see a new species begin, he did propose ideas about **speciation** that have informed and guided all further studies of the speciation process.

In thinking about the origin of species, Darwin used several key observations about life:

- The earth is millions of years old. Organisms from the distant past have left fossil remains. Most fossil species are different from the species alive today.
- Just as there is much variation between individual humans, populations of all species have variations (often only revealed by careful study of the population).
- Organisms compete—for food and space and for mates.
- When **competition** is severe, some individuals tend to survive and produce the most offspring; their offspring tend to carry the same adaptations that allowed the parents to survive and reproduce. The surviving individuals are referred to as having the most fitness.
- Populations tend to grow **exponentially** through reproduction. If left unchecked, populations would grow beyond the limits of their food sources.
- Populations change over time naturally as various adaptations are 'selected' by competition, predation, **reproductive success**, and the physical hardships and opportunities of the environment.
- Many groups of species (such as the Galapagos finches) appear to be closely related, yet each species has particular adaptations that

On Charles Darwin and the origin of species…

"Once Darwin's great idea occurred to him, he saw that it would indeed have truly revolutionary consequences, but at the outset he was not trying to explain the meaning of life, or even its origin. His aim was slightly more modest: he wanted to explain the origin of species."

Daniel C. Dennett, Darwin's Dangerous Idea

allow it to be successful in ecological conditions where other species are not so successful.

- Humans can easily modify the traits found in populations by selectively breeding individuals. (Examples studied by Darwin included pigeons, sheep and dogs.)

Darwin's general theory of evolution through **natural selection** has been confirmed or supported by thousands of observations and experiments, but the details of speciation continue to be one of the most exciting areas of investigation in biology.

Taxonomy and Naming Species

The great biologist, Carl Linneaus, started the system of **taxonomic classification** with its basic categories of kingdom, phylum, class, order, family, genus and species. Biologists create a unique name for each species of organism by combining both the species part and the genus part into the **binomial name**. For example, the grizzly bear is *Ursus arctos*, where *Ursus* is the genus part and *arctos*, the species part. Usually, two organisms may belong to the same genus if taxonomists feel they evolved from the same ancestor or one evolved from the other. The black bear, *Ursus americanus*, is a closely related species classified in the same genus with the grizzly bear. Both bears probably evolved directly from a common ancestor.

What is a species?

A species is a group of natural populations whose members can interbreed with one another but they cannot, or at least do not in nature, regularly interbreed with members of other populations from a different species. A grizzly bear is a distinct species only if it cannot or does not normally interbreed in nature with other types of bears to produce fertile offspring.

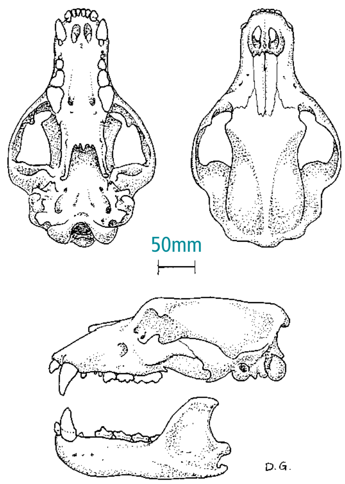
In the natural environment, grizzly bears and polar bears come into contact in some parts of their range, but the two species do not interbreed. Grizzlies and black bears also overlap in range, and they also do not interbreed.

In captivity, polar bears have bred with grizzlies to produce fertile offspring. This indicates that polar bears and grizzlies are closely related. On the other hand, captive polar bears and grizzlies generally do not breed with other bear species to produce fertile offspring.

Just how different are they? Comparing polar and grizzly bears

Zoologists often study animals by comparing them to similar species. This process helps us to understand how an animal survives in its natural environment, and why it is an interesting and unique species. Upon first comparing polar bears to other bears, many zoologists felt the observed morphology (body structure) and behaviour indicated that polar bears are not just a distinct species of bear, but they are so distinct as to warrant a completely different genus name. They named the bear, *Thalarctos maritimus*. These biologists could not imagine that polar bears and grizzlies were sibling species (derived directly from the same ancestral species), for they felt that sibling species of bears would not evolve such large differences in morphology and behaviour. Evolutionary evidence now suggests they were wrong.

Only a few polar bear fossils have been found, with the oldest less than 20,000 years old, yet they tell a fascinating story of evolution. By carefully measuring teeth size, skull dimensions, and leg bone length, researchers determined that the earliest polar bears were anatomically much closer to grizzlies. The trend over what seems to have been a relatively short period of time was rapid evolutionary change from a grizzly bear form toward the polar bear adaptations we see today.

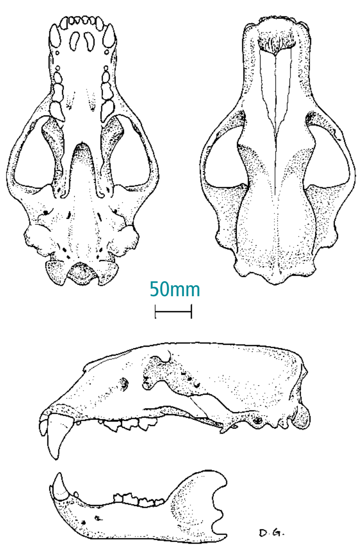


Grizzly bear skull

In recent years, molecular studies of polar bears and other bears have confirmed that the polar bear, despite its distinctive habits and anatomy, is only a short **evolutionary distance** from the grizzly. The molecules (DNA, enzymes and structural proteins) are little changed in the polar bear body from their forms in the grizzly. As molecular clocks, the molecules indicate that the polar bear split from the grizzly species less than 180 thousand years ago. On the other hand, the molecular clocks from other bears indicate that grizzlies split from their next closest relatives (black bears and Asian black bears) as long ago as 5–3 million years.

The speciation process

When a new species evolves, the process is called speciation. Because speciation usually takes place over long periods of time (possibly thousands of years), little is known about the precise mechanism. But the evidence observed to date suggests that most speciation takes place in a two-step process.



Polar bear skull

The first step involves geographical isolation of a sub-population of the species. This sub-population may be separated from the main population by a range of mountains, a river system, or it may be isolated on an island. The effect of separation is to eliminate reproduction between the original population and the isolated sub-population for many or even hundreds of generations. Another effect, **genetic drift**, may occur, especially if the isolated population is small. In genetic drift, genes in the population are actually lost in the reproductive process simply by chance events. This results from the fact that every sperm or egg carries only 1/2 of the genes of the individual, so there is a chance that some genes may never be passed along. The likelihood of genetic drift increases with smaller populations.

The second step of most speciation probably involves **reproductive isolation**. Reproductive isolation means that, even if a geographically isolated population comes back into contact with the original population, changes in the new population prevent its members from reproducing with members of the original population. The two populations may live in the same habitat but they do not interbreed to produce reproductive offspring—so they are said to be **reproductively isolated**. Usually, something about the individuals from each population prevents them from mating, and that something is called a **premating isolating mechanism**. A mating behaviour that is not suitable to the opposite mate, an unsuitable odour, or a fertility cycle that does not correspond to the other population—these are among the many types of premating isolating mechanisms.

Another type of isolating mechanism is also possible. If individuals from each population mate, but the offspring does not survive to reproduce, then the two populations are reproductively isolated. Mechanisms that function between two species after mating to prevent the production of fertile offspring are called **postmating isolating mechanisms**. Examples include situations where the offspring is not fertile (such as a mule, the sterile **hybrid** offspring of a male donkey and a female horse), or where the embryo does not develop, even though the sperm has successfully fertilized the egg.

QUESTIONS

1. Carefully examine the drawings on page 13. Describe two differences between the teeth of the grizzly bear and the teeth of polar bears. Give possible reasons for the differences. Describe one difference in the skull and explain why this difference occurs.
2. Using Table 3, compare polar bears and grizzly bears on the basis of the following features: a) legs, b) skulls, c) teeth, d) claws, e) shoulder muscles, f) fur, g) behaviour. Based on this evidence, would you consider polar bears a separate species? Would you consider them so different as to belong not only to a different species, but also to a different genus (see the sidebar *Taxonomy and Naming Species*) page 12.

Use the information in Table 3 to help answer the questions below:

3. What evidence suggests that polar bears evolved in the far north, during the ice ages? Can you suggest a scenario where a small population of grizzly bears became geographically isolated? What would the food of this population have been?

4 Suggest how natural selection on a particular geographically isolated population of grizzlies might lead to **divergent evolution** toward the polar bear? What adaptations would be selected for?

5 Can you describe scenarios where **a**) anatomical or **b**) behavioural differences between grizzlies and early polar bears may have been premating or postmating isolating mechanisms?

6 The average generation time of a grizzly or polar bear is about 10 years. Assuming that the isolation event for the founding population of polar bear ancestors was less than 20,000 years before speciation, how many generations does this represent for speciation to occur?

Table 3 – Biological Characteristics of North American Bears

Characteristic	Grizzly Bear	Black Bear	Polar Bear
teeth	Teeth are adapted for omnivore diet. Molars flattened for grinding.	Teeth are adapted for omnivore diet. Molars flattened for grinding.	Canines large and long. Pre-molars and molars adapted for shearing, biting.
skull/head	Head wide and massive - dished. Large relative to body. High forehead. Long muzzle. Flat nose tip. Eyes tiny.	Head similar to grizzly, but narrower and not 'dished', muzzle shorter.	Head longer, narrower and more tapered than other two species. Small in proportion to body. Large eyes.
jaw muscles	Powerful jaws, has been observed to bite through pine trees 20 cm in diameter.	Powerful jaws, but unable to crush large bones.	Relatively stronger jaw muscles - adapted for reliance on tearing meat (even frozen meat) and crushing bones.
feet	Massive front feet suitable for digging.	Hind feet relatively short compared to the grizzly's.	Thick padding adapted for walking on ice and snow. Massive forepaws for use as paddles. Partially webbed toes.
claws	Front claws long (to 13 cm), slightly curved. Rear claws shorter, curved.	Front claws short (to 6cm), sharply curved, tapered. Similar hind claws.	Claws black, thick, sharp, 7cm. Used to climb ice.
legs	Powerful legs. Can run in bursts up to 50 km/hour.	Legs proportionally shorter than grizzlies.	Legs relatively long, excellent running capabilities.
muscles	The grizzly's shoulder hump is formed of muscles built and anchored for digging power.	Lacks shoulder hump of massive digging muscle found in grizzly.	Powerful muscles in hind legs relative to other bears.
body form	Generally stouter than other bears, especially when well-fed.	Similar to grizzly. Does not have a shoulder hump.	Legs and neck elongated relative to other two bears.
other body features	Highly variable and diet-dependant body size and form. Its main distinguishing feature is the shoulder muscle mass.	This species exhibits a variety of colour forms, including steely blue, brown, black and white.	Stomach particularly large, capable of holding up to 70 kg of food. Can smell food up to 30 km away.
size	Has a high degree of plasticity in size: European brown bears are smaller than N.A. black bears, whereas coastal and Kodiak Island grizzlies are among the largest living bears.	Variable in size. Large black bears may be as large as small grizzlies, but these bears are shorter and stouter, than the grizzly.	The largest living bear, although some grizzlies are similar in size range. Fossils indicate this species was even larger in the recent past (few thousand years).
weight	Generally 128-317 kg (largest grizzlies are greater than 700 kg).	Generally 68-204 kg (largest black bears are greater than 350 kg).	Generally 200-450 kg (largest bears may be greater than 800 kg).

Table 3 continued – Biological Characteristics of North American Bears

Characteristic	Grizzly Bear	Black Bear	Polar Bear
current population estimates	About 200,000. Highest concentrations in Alaska and Siberia. North America 50,000-70,000.	600,000 to 750,000, all in North America. This bear is considered not threatened or endangered.	Estimates vary between 20,000 and 40,000 worldwide in polar regions. North America 17,000.
worldwide trend in range over time	Evolved in Asia (approx. 3 mybp +), spread to Europe. Probably migrated to N.A. about 50,000 years ago.	Evolved in Asia (approx. 3 mybp +), Black bears first migrated to N. A. continent about 1.5 million years ago.	Oldest known fossils are less than 20,000 years. Species has been restricted to polar and northern regions.
current and recent historic range	At one time, ranged across most of N. America, Asia, Europe and N. Africa. Now only a few in isolated pockets in S. Europe. Asian population large (120,000) but considered threatened. N.A. population extirpated or threatened in most areas except Alaska/Canada.	Ranges across most of northern North America, with patches in Florida and eastern states. Range includes most of Canada and Alaska with a swath down to north-central Mexico and California. Historic range included most of North America.	Range includes all of the Arctic regions occupied by, and fringing the Arctic ice cap.
habitat preferred	Prefers open forests, river valley bottom areas, alpine and Arctic tundra, meadows. They avoid dense forests except in coastal areas where they still seem to prefer avalanche slopes, stream, and grassy meadows. They bed in forests at the edge of meadows.	Prefers open to dense woods, and the margins of wooded areas. It will avoid open areas, especially if grizzly bears present in the area.	Ice flows, and Arctic tundra. Ocean and ice openings - they can swim up to 10 km/hour, nonstop for distances of 100 km or more.
range	8-900 square kilometres.	8-260 square kilometres.	More than 52,000 square kilometres.
food	Omnivore - eats a large variety of foods, including insects, berries, tender grass and succulent herbs, carrion. In parts of its range it is a predator on fawns, calves, and weakened large mammals (elk, reindeer, caribou, etc.). Fish and berries are important fall foods for many populations. On average, more than 75% of the nutrition comes from vegetation.	Omnivore - eats a large variety of foods, including insects, berries, carrion such as road kills, acorns, grass, dead fish, clams and shore crabs (coastal), honey, etc. Diet varies throughout the summer feeding season. Berries important at end of season. On average, more than 85% of their nutrition comes from vegetation.	Almost complete carnivore: — primarily eats seals, seal pups, and walrus pups — will eat carrion such as beached whales — occasionally eats bird eggs and berries.

Table 3 continued – Biological Characteristics of North American Bears

Characteristic	Grizzly Bear	Black Bear	Polar Bear
tree climbing	Only cubs and juveniles climb trees. Tree climbing almost always an escape or play function.	Excellent climbers from around the time they leave the den as cubs, until adults. Only older, heavier adults tend to avoid climbing trees. They climb trees for reasons other than escape, such as sleeping, feeding, shelter, protection, nursing, playing.	Do not climb trees - few, if any trees in their habitat ranges.
sexual dimorphism	Males 40%-50% larger than females. — males average 200-320 kg — females average 120-180 kg	Males 33% larger than females. — males average 90-160 kg — females average 65-102 kg	Males 25%-45% larger than females. — males average 280-350 kg — females average 180-250 kg
denning/hibernation	Embryos of fertilized females will not implant if the mother is not well-fed before denning.	Embryos of fertilized females will not implant if the mother is not well-fed before denning. Some southern populations do not hibernate.	Males and non-pregnant females do not den. Pregnant females always den. If the mother is not well-fed before denning, cubs abandoned.
first reproduction at	5-7 years	3-5 years	5-7 years
breeding period	May to mid-July in most populations.	Late March to June.	March to mid-July. Estrus lasts 3 weeks.
implantation/gestation	Unknown. Implantation probably occurs in November, near the start of winter denning. Cubs born January/February.	Total gestation 235 days. Implants up to 5 months after copulation. Cubs born January/February.	Total gestation 240-270 days. Implants in September. Cubs born in late December or January.
litter size	1-4 (average 2.12)	1-5 (average 2.25)	1-3 (average 1.76)
breeding interval	Generally 3-4 years	2 years	3.7 years average
rearing	Cubs with mothers for 2–3.5 years	Cubs with mothers for 1.5 years	Cubs with mothers for 1.5–2.5 years
nursing	Cubs nurse 5 minutes at a time, four times daily.	Cubs nurse three times daily.	Cubs nurse 15 minutes at a time, 6-7 times daily.
interbreeding?	Grizzlies and polar bears have bred in captivity producing fertile offspring.	Captive breeding with grizzly has occurred, but not fertile.	Grizzlies and polar bears have bred in captivity producing fertile offspring.

Table 3 continued – Biological Characteristics of North American Bears

Characteristic	Grizzly Bear	Black Bear	Polar Bear
defense of cubs	Females viciously defend cubs when they are threatened or attacked.	Variable. Mother usually sends her cubs up a tree. She may attack the threat, or she may run away.	Females viciously defend cubs when they are threatened. Male polar bears are most common predators on the cubs.
aggression	Some populations hunt large ungulates (elk, caribou) or small mammals (ground squirrels, marmots) regularly.	Generally not aggressive toward other predators or other large mammals.	Extremely curious and aggressive. Anything that moves in habitat is potential food.
aggression during encounters with humans	Generally not aggressive towards humans, but can be extremely aggressive in defense of young or kill. If surprised or threatened it may attack or bluff attack. Wounded bears extremely aggressive and dangerous.	Generally flees from humans unless habituated by considerable contact and access to human food or garbage. Black bears can occasionally be very dangerous, treating humans as potential food.	Extremely dangerous and aggressive in most contact circumstances.
intraspecific aggression	Encounters rare, but the fighting and injury is more common than for black bears. They have been known to fight to death.	Encounters common, actual fighting rare. They do not form groups, and they are suspicious of any other bears.	Antagonistic behaviours prevent some injury but fighting and scarring is common. They often tolerate ‘friendships’ with other polar bears.
interspecies predation	Grizzlies have been observed to attack and eat black bears.	Black bears flee from grizzlies, and will avoid encounters with them.	Interspecies aggression has been observed where habitats overlap.
enemies	Humans, mountain lions, grizzly (brown) bears. Male black bears or grizzlies, especially on cubs. Occasionally, wolves kill cubs.	Humans, larger black bears, grizzly bears, wolves.	Humans, other polar bears, killer whales. They are sometimes killed by prey (walruses, muskox). Wolves can kill cubs.

ACTIVITY 3 Grizzly Bears and Black Bears

Behaviour, Form and Function

"I am particularly entertained by writers who pad their prose with melodrama such as "the bear wielded its claws like weapons of wanton destruction," and "the hunter was doomed under the assault of the grizzly's claws which the animal flailed like rapiers of death." The claws of the brown bear are certainly a noticeable feature of the bear's anatomy, but they evolved as digging tools, not as "weapons of wanton destruction."

Wayne Lynch

Grizzly bear range has probably overlapped with the range of black bears for thousands of years. Before forest and grassland habitat became highly modified by humans, and before extensive hunting eliminated bears over much of North America, the two bears shared much of their range. To what degree do they, and did they, compete? To answer this question we need to look at the role each species plays in the community as a whole—we need to look at the ecological niche each species occupies. In fact, according to the principle of *competitive exclusion*, wherever both species play identical roles in the same community, one of the two species should be driven toward extinction.

In this activity you will compare the biology of the black and the grizzly bear, and explore insights into the way that natural selection shapes the behaviour and anatomy of an organism over time.

What we seem to want is a statistically homogenized picture of a species, when we really need to look at bears as dynamic, living mechanisms.

Dr. Barrie Gilbert

Grizzly Bear and Black Bear Ranges

YOUR TASK

Grizzlies and black bears: Competition or co-existence?

Use Table 3 and your knowledge of bear evolution and behaviour to prepare your own chart comparing grizzly bears and black bears for the following features; preferred habitat, tree climbing adaptations, digging abilities, length of parental care, and aggressive behaviour. Then answer the questions.

QUESTIONS

1 **Habitat** **a**) How do grizzlies and black bears differ in their habitat preferences? **b**) Would dense forests provide more protection than open spaces for a species of bear? **c**) Would this habitat provide more or less food? **d**) What behaviours might be required for bears living in more open areas, without ready access to forests for protective cover or climbing?

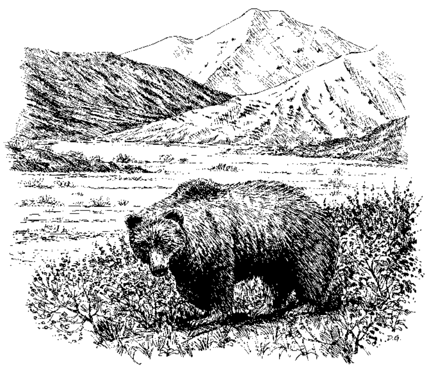
2 **Tree climbing** **a**) What anatomical/morphological adaptations might favour tree climbing in bears? **b**) How might habitat and diet be related to tree climbing? **c**) How might aggression be related to tree climbing? **d**) What differences would you expect for black bear and grizzly bear interactions in coastal areas compared to dry interior areas?

3 **Diet and food getting** **a**) What anatomical adaptations relating to food getting and diet are found in grizzlies but not in black bears. **b**) How do these adaptations affect behaviours such as tree climbing, and aggressiveness?

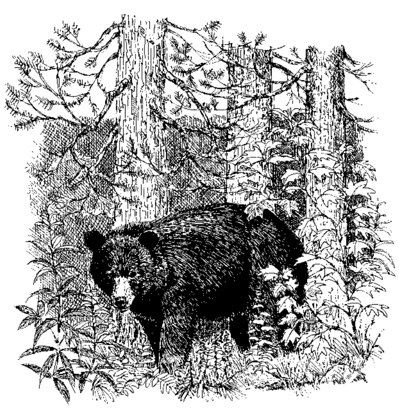
4 **Parental care** What factors might tend to select for longer parental care in grizzlies than in black bears?

5 **Aggressiveness** **a**) Consider a naive bear of each species—one that would have had no contact with humans. Which species of naive bear would tend to be more dangerous upon first contact with a human? **b**) What are the main aspects of grizzly bear biology that tend to promote more aggressive behaviour? **c**) Why are polar bears even more aggressive toward humans than are grizzlies?

6 What happens when one of the two species is removed from a range overlap? When grizzlies are extirpated from an area (as they have been in most of the southern parts of their range), would you expect black bears begin to fill the ecological role of grizzlies? If so, how would this affect evolutionary trends in the black bear species?



Grizzly Bear and Black Bear Habitats



7 **a**) Does the principle of competitive exclusion apply to bears and humans? **b**) In what ways are humans competing for the ecological niche of grizzlies?

Some Conclusions

- Grizzly bears and black bears do not have identical ecological niches, but they do have overlaps in much of their ecology, range and behaviour. Competition is a strong force in natural selection which has favoured the separation of black bear and grizzly bear ecological niches.
- The biology of these bears does not necessarily challenge the principle of competitive exclusion, but it certainly points out that the principle should be interpreted in 'degrees of competition'. Grizzlies and black bears compete but not everywhere in their ecological niches.

ACTIVITY 4

Population Studies

If you were a scientist studying grizzly bears in a wild, rugged mountain ecosystem, how would you count them? Would it be difficult to find them? When you find them, how would you distinguish one from another?

Studying bears is far from easy… If the number of bears in a population is not known, incorrect management decisions can be made... Changes in population… such as shifts in the age or sex composition, are not always apparent and may not be noticed until the damage has been done.

Andrew Derocher, 'Why are bears so vulnerable'

(In Ian Stirling "Bears, Majestic Creatures of the Wild")

Bears are secretive. They often move daily many kilometres to a food supply. They are more active around dawn and dusk and they sometimes travel at night. They have a keen sense of smell, and they generally avoid humans. How would you study such a complex animal? How would you know whether a population was increasing or decreasing? How would you predict whether your children or grandchildren would be able to study grizzlies in this same wilderness—whether there would still be bears there in the future?

In this activity you will explore the way that scientists count bears and estimate populations, and then solve some simple population problems.

Counting bears

Fresh bear sign indicates that bears occupy an area. **Scat**, tracks, hair tufts on branches and fresh scratch marks on trees are among the different signs you can look for to determine if bears are present. But would you be able to tell a grizzly scat from one left by a black bear? Could you distinguish between grizzly tracks and tracks made by black bears? Could you tell if hairs left on a branch were left by a grizzly or some other animal? Observations by experienced observers can help to determine the **absence/presence** of bears in an area. This information can be used to determine the need for detailed population studies.

In the past, to accurately count grizzly bears has been a difficult, dangerous and costly task involving helicopter travel, bear trapping and handling, and stress on both bears and bear biologists. Modern technology and innovative new techniques are making the science of bear counting easier and safer for both scientists and bears.

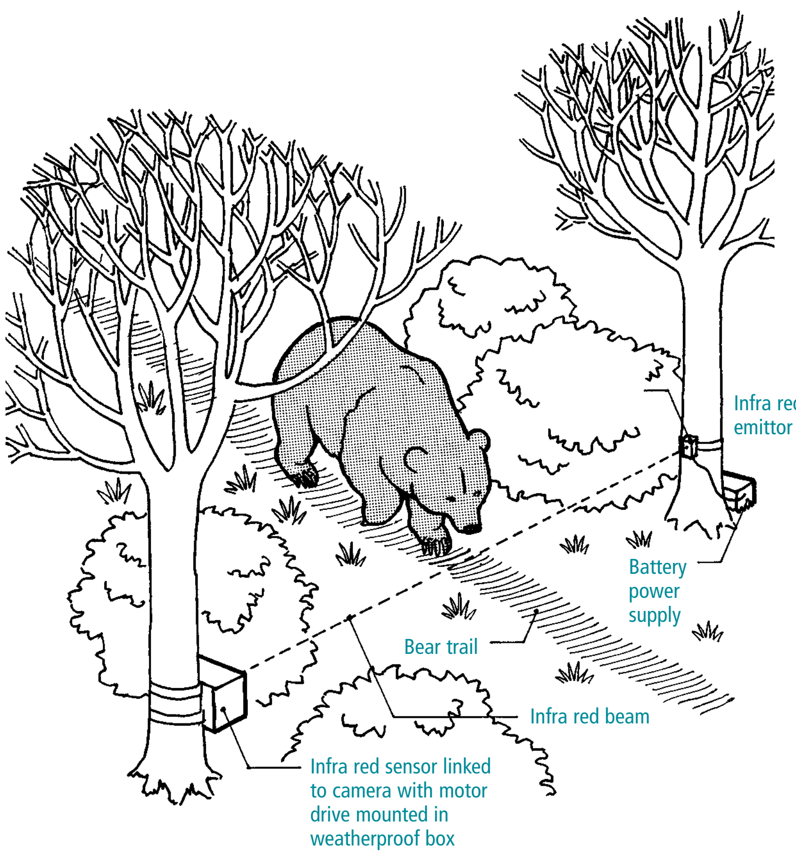
Calling All Bears

Since the 1960s, radio technology has been used to study wildlife. Animals are captured, fitted with a radio collar, and then tracked by radio-location for months or even years. Radio collaring is used to monitor movements, feeding, or resting. Using radio tracking, scientists can follow bears through the seasons and locate their denning sites to study hibernation.

Radio collaring is also an important tool for counting bear populations. As long as a radio collar stays on a bear, that bear is 'marked' and it can be identified. Wildlife biologists use radio-collared bears in 'capture-mark-resighting' methods to calculate the size of bear populations (see sidebar).

Click, You're on Candid Camera

Few people have the skills, patience and time required to count individual bears in a wilderness population. But what if you could leave a set of eyes here and there in the forest to 'watch' for bears?



When the bear breaks the infra red beam, the camera automatically takes a picture and winds on, ready for the next exposure.

Capture-Mark-Resighting

If you want a good count of a grizzly population, must you capture and mark every individual? No.

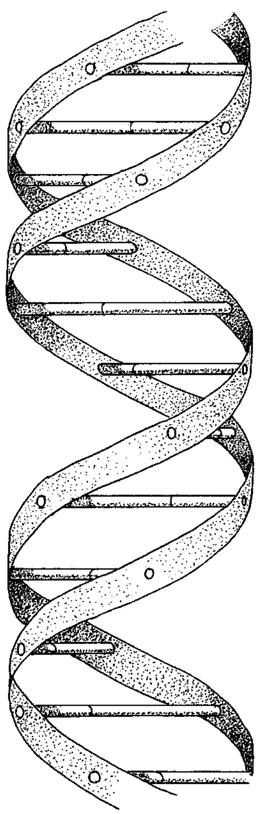
Suppose you quickly capture 12 grizzlies from across the entire range of a population and mark each individual. (You could put on a radio collar, or a highly visible spot of paint where it would not harm the animal). Now suppose that you wait a couple weeks until the bears are once again dispersed over the region, and then you make a count of grizzlies in the area. Suppose this time that you sight 20 different grizzlies, and four of them had been marked by you previously. How many grizzlies in the entire population?

Obviously, you sighted one-third of the 'marked' grizzlies. To see all of the bears you marked you would need to sight three times as many bears. This means that the total bear population is 60 grizzlies.

Although this is a simple case, it shows how biologists estimate populations using this **capture-mark-resight** method.

Wildlife biologists use **remote cameras** to take pictures of animals in the forest. A battery-powered camera is attached to a tree and is fitted with a flash unit. A special infra-red sensor detects when an animal is walking through the camera's field of view. The camera and flash 'capture' a picture of each bear (or any other large animal) traveling through the field of view.

Using several remote cameras in a forest area, biologists collect pictures that become data for capture-mark-resight calculations.



The Power of Fingerprints

Every human has a unique set of fingerprints. Now, DNA, the key information molecule found in all life, can be used to make 'molecular fingerprints' of an individual organism.

Making a **DNA fingerprint** is not as easy as 'lifting' a human fingerprint from the scene of a crime. You need a lab equipped for modern biochemical procedures.

Researchers start with a hair collected from barb-wire positioned around bait in the forest. In the lab, the base of the hair is digested by enzymes and its DNA molecules separated out. Then the DNA is broken down into fragments. By analysing the sequence of molecular building blocks in the DNA fragments, researchers get a bear 'fingerprint'. Bears that are closely related, such as mother and her cub, will have very similar DNA fingerprints. Bears not related by family ties will tend to have more variation in their DNA fingerprints.

Wildlife biologists are beginning to use DNA fingerprints to count bears. It is not necessary to see the bear—researchers must only collect its hair or scat. Eventually, if enough samples of hair are analysed, the DNA fingerprint of each individual bear in the population will be known—a complete population count! Otherwise DNA figureprints can be used in capture-mark-resighting studies to estimate population (see sidebar page 24).

As the use of DNA fingerprinting grows, this fascinating new method of counting bears will help biologists manage and protect populations of grizzlies.

Predicting Population Change

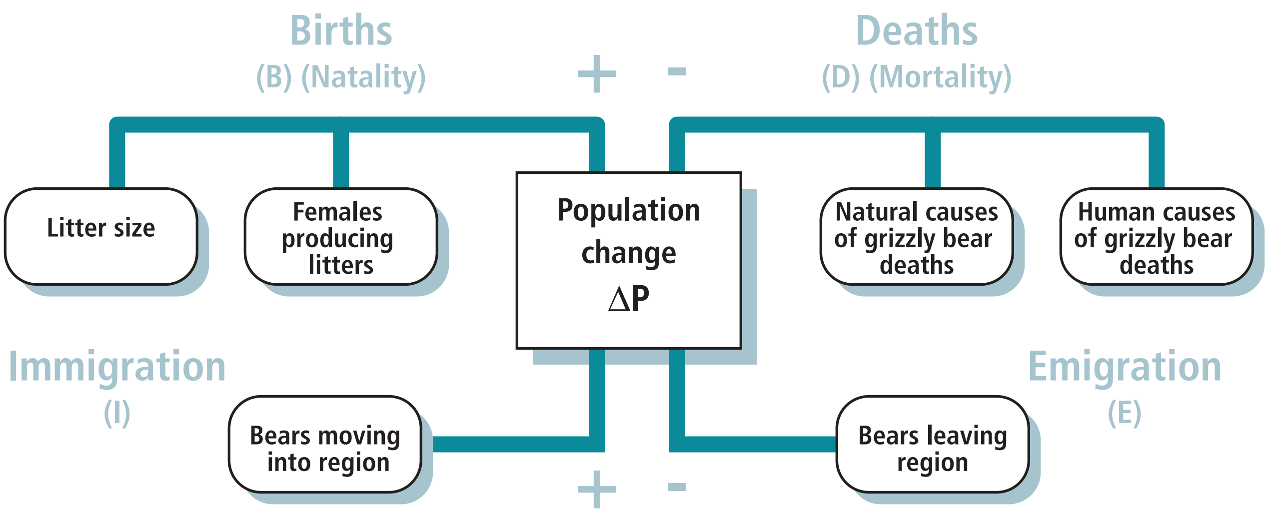
At the heart of population studies is predicting how the size of a population will change over time. Four basic factors are involved in population changes:

Births or **Natality** (**B**) - number of Births in the population

Deaths or **Mortality** (**D**) - number of Deaths in the population

Immigration (**I**) - number of individuals moving into the population

Emigration (**E**) - number of individuals leaving the population



Basic Factors in Grizzly Bear Population Changes

Growth in population can be expressed by the equation:

$$\Delta P = [B + I] - [D + E]$$

or

Change in Population = [Births + Immigration] minus [Deaths + Emigration]

To calculate Births (B) one needs to know the number of reproductive-age females in the population (N_{rf}), the average interval between litters (L_i), and the average number of cubs in a litter(N_{avelit}). The Natality (B) is then determined by the following:

$$B = N_{rf} \times N_{avelit}/L_i$$

or

Births (B) = number of reproductive females x average number of cubs per litter divided by the interval between litters.

QUESTIONS

1 Why is it so important to know the size of grizzly populations? Who cares? Why should they care?

2 When people talk about managing bears, what do they mean? Who (what person or people) manages bears?

3 What human behaviors need to be managed on the basis of information about grizzly bear populations? Why do these behaviours need to be managed?

4 Values for several variables relating to two different grizzly bear populations, one population from Area A, another from from Area B, are provided in the table below. Each row represents data taken in a single year. Calculate the change in population (ΔP) for each population that year. Did the population grow or decline?

- number of bears to start with (**N_{start}**)
- number of reproductive age females in the population (**N_{rf}**)
- average number of cubs in litter (**N_{avelit}**)
- interval between litters (**L_i**)
- immigration into region (**I**)
- natural mortality due to disease and age, etc. (**D_n**)
- cub mortality (**D_c**)*
- human hunting kills (**D_h**)
- human-caused mortality of 'nuisance' bears (**D_{nu}**)
- deaths caused by poaching or other illegal killing of bears (**D_{ik}**)
- emigration of bears from the area occupied by the population (**E**)

		Natality Information				Mortality Information					
Area	**N_{start}**	**N_{rf}**	**N_{avelit}**	**L_i**	**I**	**D_n**	**D_c**	**D_h**	**D_{nu}**	**D_{ik}**	**E**
A	806	185	2.3	3.3	7	64	21	32	6	22 (est)	2
B	421	104	2.2	3.8	2	33	11	11	0	0 (est)	5

* Cub mortality is not constant during the three years cubs are with their mothers. Factors affecting mortality include such things as the amount of effort a mother puts into guarding the cubs, the amount of nutrition cubs get from their mother's milk versus nutrition from other foods, and the ability of the cub to look after itself. The values provided here represent a *combined mortality* for all three years of the cub's life with its mother. As you will see in the next activity, more sophisticated treatments take into account the different mortalities of cubs as they age through their first 3 years.

5 Work with a small group for this task. Pick out one of the cards from the card set describing factors that might affect grizzly bear population changes. This card set is located under Activity 4 in the Teacher's Guide. Use Diagram 1 above, and Table 3: *Biological Characteristics of North American Bears*, p. 16 in this Guide as important information tools to help you speculate on the nature of changes that might occur in a grizzly bear population as a result of the factor on the card you chose. Discuss in your study/discussion group. Do this for a number of factors. Then share some of your insights with the rest of the class.

ACTIVITY 5

Grizzly Bear
Population Dynamics

The Life Table

The grizzly population wandered through the sagebrush country and across the alpine meadows, roamed the coniferous forests, swam the rivers, and climbed the multi-flowered mountain slopes within the… ecosystem. At times it was widely dispersed throughout this extensive wilderness area, some bears living in family groups, others as lone males or young females.

F. Craighead

How do populations of animals in an ecosystem change from year to year? What happens to populations when they are hunted? What happens to a population during a year when food crops fail? These questions are at the core of population ecology—the field of biology used by wildlife managers as they monitor and conserve species such as the grizzly bear.

Activity 4 looked at an equation for population change for grizzly bears. In this Activity, we examine a model of population change called a **life table**. A life table uses the following information to predict patterns of population change:

- the number of individuals at each age level (the age-class structure of the population),
- the **survivorship** (S_x) for different age classes (where x represents the age of the animal in years. For example, S_3, is the average survivorship for bears in the third year of their lives).
- the reproductive rate (m_x) for different age classes (where x represents the age of the animal in years. For example, m_{10}, is the average reproductive rate for females in the tenth year of their lives).

In practice, for most species, life history tables use values and population numbers for females only, since females determine reproductive rates and population growth. A population of 1000 females is used by convention. (For most species, the number of males in a population is about equal to the number of females. This means that you can double the female population figures to estimate total population).

Sample calculation

A type of rodent lives for three years. Females in a population of this rodent have an average of 4.26 offspring in the second year of their lives (they reproduce only this year). The sex ratio of offspring is 1:1. (Therefore, reproductive rate is 2.13 female offspring/female/ year).

After the first year, 94% of the population is still alive. Of these, 50% are alive at the end of their second year and all are dead by the end of the third year. Therefore,

$S_1 = 0.94$; $S_2 = 0.50$, and $S_3 = 0$. Let's set up a life table for this rodent based on a population of 1000 females.

Step 1: Finding the age-class structure

- Let y = number of females in age class 0–1. Of these, 94% will live, so the number in age class 1–2 is 0.94y. Of these 50% will live, so the number in age class 2–3 is 0.50(0.94y).
- Thus the total number in all three age classes is: y + 0.94y + 0.5(0.94)y = 1000
- Solving for y:

$$2.41y = 1000$$
$$y = 415 \text{ (age 0-1 population)}$$
$$.94y = 390 \text{ (age 1-2 population)}$$
$$.47y = 195 \text{ (age 2-3 population)}$$

Step 2: Build the life history table for this rodent population

Age Class	Pop #	Survivorship S_x	Reproductive rate = m_x	$S_x m_x$
0–1	415	0.94		
1–2	390	0.50	2.13	1.065
2–3	195	0.0		

Step 3: Is this population growing?

To answer this question, we need to look at the number of offspring that will be born. This will determine the population of the next year's 0–1 age class.

Since (in this simple model) offspring are born only to age class 1–2 females, at the rate of 2.13 female offspring per female per year, and since only 50% of the females of this age class survive (it is assumed that only survivors successfully reproduce), then the number of surviving female offspring is:

$$390 (S_x m_x) = 390 (1.065) = 415$$

As you can see, the number of female offspring born is the same as the previous year's age 0–1 population. So the second year of a life table for this rodent population will look the same as the first.

Conclusion: The population is neither growing nor declining, but remains steady.

QUESTION

1 If you change the survivorship of any age group, or the reproductive rate, what would happen to the age class structure? Try changing one of these variables slightly and recalculate the table for the new values.

YOUR TASK

Building and Interpreting a Life Table for Grizzly Bears

In the simplified example of a rodent population above, it is relatively easy to calculate the age-class structure. Grizzly bears have a more complex life history. For example, they live longer, start reproducing at 6+ years, and have litters at intervals of 3 or more years. But it is still possible to model grizzly bear population dynamics in a life table using a computer spreadsheet.

Instructions for setting up a grizzly bear life table model on computer spreadsheet are provided in the Teacher's Guide. Once the table is set up you will work on the spreadsheet to answer a set of questions below. The spreadsheet is set up for a population containing 1000 females and you will manipulate the following variables:

age class Use column **B** to change values in each age class as desired. (Values in column **F** are repeated from column **B** and will change automatically).

S_c Survivorship of cubs. Change cell **C3**.

S_y Survivorship of yearlings. Change cell **C4**.

S_s Survivorship of subadults. Change cell **C5**.

S_a Survivorship of adults. Change cell **C9**.

m_x Average reproductive rate of population as number of female cubs per adult female per year. Change cell **D9**.

Always save an extra copy of your spreadsheet, so that you can always recover your original set up. A printed copy of your spreadsheet in its original form may also be useful. Most spreadsheet applications will allow you to graph your life table sets. If possible, provide a graph of population trend with your answer to each question.

QUESTIONS

2 Suppose there is a bad year for cubs and only 1/2 of those born in a certain year survive. How long will it take the population to recover?

3 Suppose there are extremely harsh conditions in the spring for 5 years in a row, leading to poor food supplies at this early time of the year. This might cause the survivorship of cubs of the year (age class 0-1)to fall to 70% and survivorship of age class 1-2 cubs to fall to 75% for 5 years in a row (Change cells in column B, not C, to model). How will this affect the population? Is it likely that reproductive rate would remain unchanged during these years of harsh conditions? If not, would changes in reproductive rate increase population or lower it further?

4 What happens to the population if 4% of the adult males are hunted each year? What happens if 1% of the adult females are hunted each year?

5 There is some thought among bear biologists that hunting mature dominant males in a grizzly bear population opens up habitat for the increased survivorship of subadult males or immigration from surrounding home ranges. It is thought that subadult males might increase cub mortality by preying on the cubs - this may improve their chances to mate with more females, since there will be an increase in the number of females coming into estrus. Model this situation for a series of decreasing cub survivorship values.

6 Are small populations of bears more sensitive to certain events than large populations? Change your age class structure from 1000 females to 100 females by dividing each age class (column B) by 10. Now experiment with the scenario where 5 females are removed from the population by poaching or other illegal killing. How long is required for the population to recover from this killing? If continued poaching of females occurs, what will be the effect on the population?

Part B. North Flathead Grizzly Bear Population Dynamics

One of the most extensive studies of grizzly population dynamics is the work of Bruce McLellan and his colleagues on the North Fork Flathead population in Southeastern British Columbia. Based on hundreds of **mark-recapture** observations with radio-collared bears, they have determined the following values for this population:

$$S_c = 0.867;\ S_y = 0.944;\ S_s = 0.931;\ S_a = 0.946;\ m_x = 0.422$$

Use the following age-class structure to set up a model of the North Fork Flathead population based on a population of 1000 females:

0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	21+
92	80	75	70	65	61	57	54	51	48	45	43	41	39	36	34	32	29	23	16	9

QUESTIONS

7 What is the expected doubling time for this population?

8 Is it possible that this population can experience growth of this magnitude over long periods of time? What might be happening to the many 'extra' bears born in this region?

Part C. Another example

A valley system adjacent to the North Fork Flathead River is the South Fork Flathead River. Population studies in this valley reveal a different set of grizzly bear reproductive and survival values:

$$S_c = 0.86;\ S_y = 0.85;\ S_s = 0.80;\ S_a = 0.88;\ m_x = 0.39$$

10 What is happening to this population?

11 If it were isolated from other grizzly populations, what would happen to this population in the long run? What might be the role of immigration into this area from other regions such as the N. Fork Flathead?

12 Studies have shown that illegal hunting, natural deaths, and deaths related to human garbage management are the main causes for the high adult mortality in this population. Can you recommend management policies that might help to conserve this population?

ACTIVITY 6

Grizzly

Feeding, Habitat and Populations

To understand the ecology and behaviour of grizzly bears (Ursus arctos), knowledge of their diet is essential. It is not surprising that there is a strong relationship between food quantity and quality and reproductive rates, and some populations appear to be ultimately regulated by food.

Bruce McLellan and Fred Hovey

A Varied Diet

To survive and reproduce, a grizzly bear must have a good food supply. Like humans, grizzly bears are omnivores; they eat a variety of foods including plants, berries, fish, meat, and occasionally even mushrooms and insects. Studies of grizzly diets have shown that for most populations, as much as 85% or more of their energy comes from eating plant materials. Grasses, sedges, skunk cabbage, cow parsnip, huckleberries, the roots of many different plants, and pine nuts are among the many plant foods eaten. When grizzlies do eat meat it is often the rotting carcasses of dead animals they find with their keen senses of smell.

Also like humans, individual grizzlies show a remarkable variety of food preferences and food-getting abilities. Young grizzlies learn hunting and foraging techniques from their mothers, so special skills may actually be passed along for many generations. In Alaska's Katmai National Monument, a grizzly stands at a precise location on the edge of a 2-metre waterfall. As salmon hurl themselves up and over the falls, she snaps them out of the air with her powerful jaws. Over the years, observers have witnessed the female teaching this skill to her cubs.

Special Energy Requirements

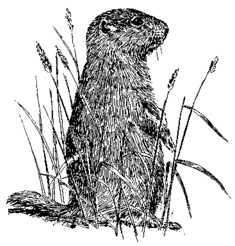
In deer, moose and elk, compartments of the digestive system including the rumen provide special digestive cauldrons where nutrients from plants can be extracted, largely through the action of bacteria. Grizzlies lack this adaptation, and so they must process more plant food or 'higher quality' plant food through their digestive systems to get enough fat, protein and energy. In proportion to their body size, they have a longer intestine than any other family of carnivores, and this helps them to extract more energy from plant foods.

During winter, many plant foods normally eaten by grizzlies are covered by snow. Succulent leaves wither and decay on the ground. Grizzlies have evolved to hibernate and so they avoid the difficulties of winter foraging. Bear species living in the tropics, such as the sun bear of Asia, do not hibernate.

Cow Parsnip

Grizzly hibernation is not complete hibernation as in squirrels and marmots where the body temperature is lowered and metabolism is minimized. Instead, grizzlies maintain a constant metabolism. Their bodies remain near normal temperatures, although the breathing rate slows. In the den for 5 months or more, they burn off as much as 1/2 of their body weight! They do not eat, drink, urinate or defecate!

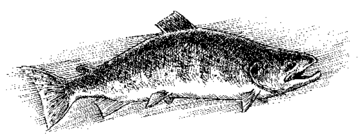
While the spring and early summer are dedicated to survival, bears do not put on much weight until two or more months after emerging from hibernation. Late summer and fall are critical times to put on extra fat for the next hibernation. If a grizzly does not put on enough fat by the time of denning in November, it may not survive the winter.



Ground Squirrel

Reproduction and Feeding

Feeding and hibernation have important effects on grizzly reproduction. Mating takes place in May or June. Embryonic growth requires about two months, but the cubs are born eight months after mating, in January or February, as the female hibernates in her den.



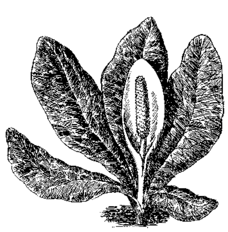
Salmon

The strategy that stretches gestation to eight months is called **delayed implantation**. The female holds the fertilized egg until after she settles into the den; then it is implanted in the uterus, but only if the female has enough fat from her diet to allow the survival of both her and her cubs. If not, she will abort the fertilized eggs. This type of natural abortion prevents the female from wasting energy on cubs that are not likely to survive.

Sedge

Studies of Grizzly Diets

Biologists have begun to make detailed studies of grizzly diets. The graphs on page 37 are a summary of two such studies (MacHutchon, Himmer, and Bryden, 1993; McLellan, and Hovey, 1995) that involved carefully collecting and analyzing the scats left by grizzly bears.

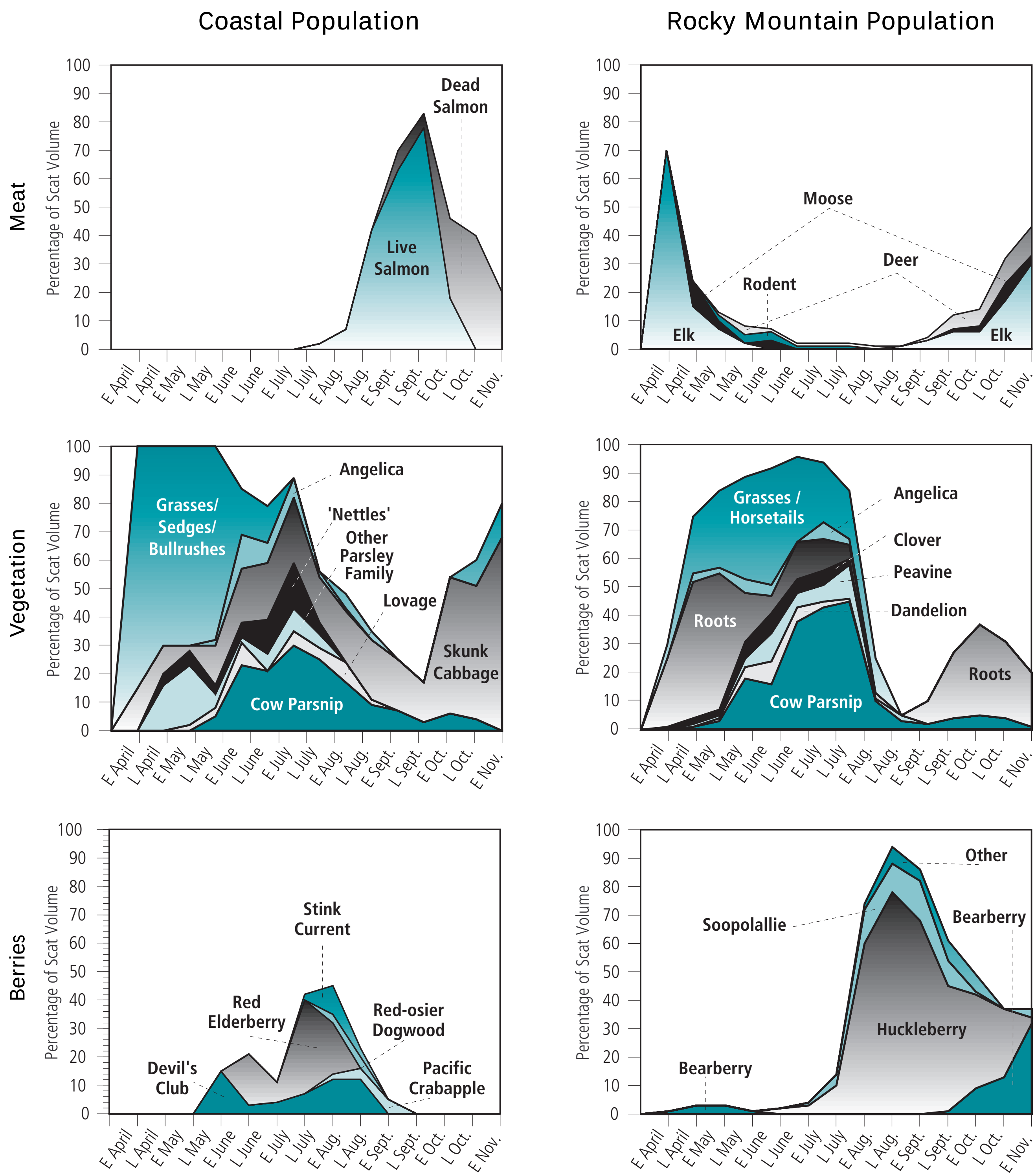


Skunk Cabbage

In the coastal study (Khutzeymateen Valley) about 500 bear scats were analyzed. These bears fed on 65 different foods, but only the main food items are shown in the graphs. During the three years of the study researchers noticed a large variation in the availability and abundance of food items, and this had a critical effect on how the bears met their energy needs. Plant foods abundant in some years were harder to find in others. The timing and abundance of salmon returning up their spawning rivers varied from year to year. But even in years marked by

Diets of Coastal Grizzlies and Interior Grizzlies Compared

The graphs below show the amount of food eaten by grizzly bears as determined by analysis of scats of two different grizzly bear populations. Coastal population graphs (Khutzeymateen Valley) average about 3 years of data, while the Rocky Mountain population graphs (N. Fork Flathead River) average about 12 years of studies.



a glut of spawning salmon, the bears needed to feed constantly on plant foods throughout the entire summer.

The Rocky Mountain study followed a population of grizzlies for 12 years. During this time 1100 scats were collected and analyzed. As with the coastal population, the study found that diet varies from year to year depending on the availability of food **resources**. In some years, animal carcasses were more available, while in other years, certain plant foods were delayed by a late spring or covered by an early snow-fall. The crop of huckleberries was particularly important in shaping the bears' feeding behaviour. In years with poor huckleberry crops, bears shifted their attentions to less desirable crops such as late-season cow parsnip, or they spent more time than usual digging roots.

QUESTIONS

Refer to the "Diets of Coastal Grizzlies and Interior Grizzlies" graphs on page 37 to answer the following questions:

1 Compare and contrast coastal grizzly diets with interior grizzly diets for the following:

- **a** the main foods eaten upon emergence from the den in early spring
- **b** the relative importance of berries in the diet
- **c** the four main sources of energy for each of the two populations
- **d** the relative importance of meat in the diet
- **e** differences in the types and timing of meat consumption
- **f** the main foods eaten just before entering the den in late fall.

2 Many populations of grizzlies are under pressure from human developments in areas where they would normally feed. For each of the following hypothetical scenarios, discuss the possible impacts of the development on grizzly feeding biology. (You may wish to model these impacts using the grizzly life table spreadsheet developed for Activity 6). Also, suggest management options that: i) meet the feeding behaviour needs of grizzlies, ii) might meet the needs of the grizzly population and still allow the development.

- **a** A proposed ski area development has been made for a site where huckleberries are particularly abundant and a concentration of grizzlies is known to feed in the area.

- **b** A proposal has been made to a National Park by mink ranchers to use helicopters in early spring to find and remove overwinter kills of elk and deer from the park to be used in their mink farms as food.
- **c** A coastal valley logging plan proposes to build roads through portions of the riparian zone of a large valley. Sedge wetlands and skunk cabbage swamps will be altered. Salmon populations will be affected by development along the river.
- **d** Several groups have suggested increasing the allowable harvest of salmon from the mouth of a wilderness coastal river.
- **e** A major highway through an interior wilderness valley has been proposed. On one side of the valley are abundant crops of huckleberries and hedysarum (hedysarum plants are an important source of roots for interior grizzlies). On the other side of the valley, avalanche slopes contain rich crops of cow parsnip. Elk and deer winter on the side with south-facing slopes, while grizzlies den high up on the slopes that face north.

3 Biologists and wildlife managers use **habitat assessment** to determine the **carrying capacity** of the land. But grizzly bear population densities and home ranges vary considerably. Bears in coastal habitats of B.C. and Alaska may live in population densities averaging 3.5 km^2/bear. In the interior of BC and in Northern Canada and Alaska, grizzly bear densities tend to be much lower - the average amount of habitat required per bear may be as much as 130 km^2 or more. From what you know about grizzly biology, what factors should be considered in determining the grizzly bear carrying capacity of wilderness areas?

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Glossary

absence/presence a measure of whether or not an animal occupies a region.

adaptation biological traits of an organism, such as body form, metabolism or behaviours, that provide the organism with fitness for its environment. Also, the process by which an organism becomes fit for its environment through natural selection.

adaptive radiation the formation of two or more new species from a single ancestral group, usually in response to the availability of unoccupied ecological niches.

age-class structure a breakdown of the numbers of individuals in a population according to age.

alleles, allelic frequencies the alternate genes at a particular chromosome site. The frequency, usually expressed as a decimal, of one allele in a population. The total of the allele frequencies for one gene will be one.

allopatric speciation speciation that occurs as a result of geographic separation of a population of organisms.

analogous structure similar in function but not in structure. Structures are analogous if they perform similar roles but did not evolve from the same structures. The wings of birds and the wings of insects are analogous structures.

biodiversity the diversity of living organisms in a habitat, ecosystem, or other ecological unit. Biodiversity studies look at the diversity in species, genetic variation within each species, and the habitat required for species. Biodiversity is mainly associated with the conservation of our biological heritage.

capture–mark–resight a technique in ecology and wildlife biology for estimating population size based on:
1) an initial capture of a portion of the population;
2) marking individuals captured; and
3) following dispersal of the marked individuals, a count of a portion of the population is taken. The total population size is then calculated from the data.

carrying capacity the largest number of organisms of a particular species that can be maintained indefinitely in an ecosystem.

chromosome the rod-shaped units in the nucleus seen during cell division that contain the genes.

classification in biology, the process of assigning organisms into categories such as kingdom, phylum, class, order, family, genus, species based on characteristics.

common ancestor a species (or individual in a species) from which two or more species (individuals) have descended.

comparative anatomy using body structure to determine evolutionary origins and relationships.

competition in biology, the interaction between different members of the same or different species for a resource required by both.

convergence, convergent evolution evolution where two distinct phylogenetic lines are shaped by similar ecological pressures that lead to similarities in form and function. Examples include the convergence of marsupials in Australia to forms similar to placental mammals in other continents. Ecological roles in one environment (such as the role played by flying squirrels) are filled by animals with similar characteristics (sugar gliders) in Australia.

delayed implantation a process in some mammals (e.g., seals, sealions, bears) where implantation of the fertilized egg into the uterus is delayed. Embryonic development is mostly suspended during the delay and then begins at implantation.

divergence, divergent evolution evolution shaped by speciation that leads to the derived species filling a new ecological role.

diversification biologically, the evolution of a species into many ecological niches. See adaptive radiation.

DNA fingerprinting a technique in molecular biology that uses an analysis of the components of specific fragments of an individual's DNA to show a pattern.

ecological niche the functional role and position of an organism in the ecosystem.

emigration (**E**) movement of individuals of a species out of a region or ecosystem.

evolutionary distance the evolutionary distance between two species is, effectively, the amount of time since the two species had a common ancestor. The evolutionary distance between polar bears and grizzly bears, with a common ancestor only 20,000 years ago, is much less than between grizzly bears and humans, which had a common ancestor many millions of years ago.

evolutionary tree a representation of evolutionary relationships between organisms in the shape of a tree-like structure. Branching indicates divergence from a common ancestor.

exponential growth growth of a population based on a percentage increase in the population each year.

extant species a species living today.

extinction, extinct species when a species ceases to exist as a reproducing population. A species that is no longer living anywhere in its range.

founder population a population of a species, usually relatively small, that becomes isolated from other populations. If it survives, remains geographically isolated, and experiences different evolutionary pressures than the parent population, natural selection working on this population, along with genetic drift, may lead to speciation.

genetic drift the selection of a subset of the genes in an entire population by chance during gamete formation where only 1/2 of the genes of individuals are passed on to gametes. In evolutionary terms, genetic drift becomes important in small populations.

habitat assessment using detailed vegetation and terrain maps, satellite photos, and aerial photos to determine the amount of potential habitat for wildlife in an area.

homologous structures structures in two different species that are derived from a structure in a common ancestor.

hybrid offspring of two parents of different species.

hybridization the mating of two separate species and the formation of a reproductively viable daughter species.

immigration (**I**) movement of individuals of a species into of a region or ecosystem.

life table a table showing the age class structure of a population over time.

mark-recapture see capture-mark-re-capture.

minimum viable population a population level, below which the species can no longer maintain itself through normal reproduction. Factors such as access to mates or genetic drift become more important in small populations.

mortality (**D**) the death rate or number of deaths in a population per unit of time.

natality (**B**) the birth rate or number of births in a population per unit of time.

natural selection increase in number of individuals carrying traits that are better adapted toward selection pressures such as physical conditions, competition, predation, etc. by the fact that such adaptations tend to confer a higher likelihood of survival and reproduction.

nuisance bears a subjective term applied to bears involved in bear/ human conflict. Usually, bears habituated to humans, unafraid of humans, or dangerous to any human activity are considered nuisance bears.

omnivore feeds on both plant food and animal food.

paleontology the study of fossils and their implications for evolution and ecology of life over the course of the earth's history.

phyletic change (phyletic evolution) gradual change within a single lineage over time; a species changes slowly over time without splitting so that a lineage could be said to be made of various species separated in time, or "chronospecies".

phylogeny establishing relationships among species of organisms based on evolutionary change. Phylogeny is concerned with the history of species and groups of related species.

postmating mechanisms mechanisms that function between two species after mating to prevent the production of fertile offspring. Postmating mechanisms are rarely important in nature due to sexual selection which tends to favour mechanisms to prevent nonproductive matings.

premating mechanisms mechanisms that act to prevent interspecies matings. through such things as: behavioural rituals; visual, auditory, or olfactory signals; and temporal differences such as the timing of estrus.

principle of competitive exclusion the observation that no two species can continue to compete for the same exact resources since one species will eventually become extinct.

punctuated equilibrium a model or the mechanism of evolutionary change that proposes that long periods of no change (stasis) are punctuated by periods of rapid speciation, with natural selection acting on species as well as on individuals.

refugia referring to regions that escape being covered by glaciers during the ice ages, while surrounding areas are ice-covered.

remote camera in wildlife biology, an automatic camera triggered by wildlife.

reproductive isolation (genetic isolation) when two populations (sibling species derived through descent from the same species) are not interbreeding even though they may occupy the same geographical area. Geographical, anatomical, physiological, or behavioural mechanisms prevent interbreeding.

reproductive success a measure of the relative number of offspring parented by individuals of a species. Individuals with high levels of reproductive success are contributing more of their genes to future generations.

resource partitioning the use of a number of similar resources by more than one species, with each species better adapted to utilize its preferred resource(s). For example, several species of monkeys can live in a small area of tropical forest by partitioning food resources. One species may feed on the forest floor, another at mid-level, and yet another at the top. Also, a species may eat fruits of one tree while another eats the leaves, and yet another may feed on the bark.

scat feces.

selective breeding the process whereby humans select individuals of a species (such as a plant or farm animal) and then control breeding over several generations in order to emphasize the combination of desirable traits in the offspring.

speciation the process of new species arising from existing species.

species a group of natural populations whose members can interbreed with one another but cannot (or at least do not) interbreed with members of other such groups.

survivorship a decimal number between 0 and 1 indicating the fraction of survivors predicted for an age class. Survivorship is usually expressed by the term S_x, where x in age. For example, S_3 is the survivorship of members of the population during the third year of life.

sympatric speciation Speciation that occurs without geographic separation of a population of organisms; often occurs as a result of hybridization accompanied by polyploidy; but may also occur as a result of disruptive selection.

tagging a technique in wildlife biology where individuals are tagged or marked in some way (radio-collar, painted mark, ear tag, leg band, etc.) so that the individual can be recognized.

A Web-Link Bibliography for Bear Biology Sites

Links Updated March, 2000 for
Grizzly Bear Biology

Evolution

Evolution of Bears - From the Bear Den	Useful short introduction to the evolution of bears.

Ecology

Saving Berries for the Bears	Information about a proposal to protect grizzly bear foods and grizzly bear habitat during forestry operations. Important reading for students of Grizzly Bear Biology 11.
A year of the black bear	Provides a brief summary of the life and feeding of a black bear throughout the year. Useful for comparing black bear ecology with that of the grizzly bear.

Conservation

Essay on bear conservation	Bear Conservation Around the World, by Christopher Servheen. An excellent short aticle by one of the world's authorities on bear conservation.
The International Association for Bear Research and Management (IBA)	A provessional organisation specializing in bear biology. Their site has a good section on species descriptions of all living bears.
Interagency Grizzly Bear Committee	Created in 1983 to lead the recovery of the grizzly bear in the lower 48 states. Includes up-to-date information on "bear spray".
Craighead Environmental Research Institute	Specialising in conservation biology with a focus on grizzly bears, other carnivores, and their habitats. This site includes information on DNA paternity studies with grizzly bears, along with some faxcinating scientific results. Highly recommended for Grizzly Biology 11 students! Also on the site - information about the conservation status of grizzly bears around the world.
Grizzly Discovery Center	Educational facility devoted to the preservation of bears and wolves in the Yellowstone National Park.
Vital Ground Foundation	Land conservation organisation working to preserve grizzly bears and their habitat. Includes information about Bart The Bear, a famous bear with over 12 featurefilm roles to his credit.
Sierra Club Grizzly Bear Ecosystems Project	A site about the ecology and conservation of grizzly bears in Yellowstone National Park.
Northwest Wildlife Preservatioin Society	Created in 1987, NWPS's mission is to develop and provide educational, research, and advisory services that can advance the public's awareness and knowledge about wildlife systems in northwest North America. Includes information on the biology of black bears and grizzlies.

General Biology - North American Bears

Center For Wildlife Information	Has information on all three North Americal Bears.
North American Bear Center	Useful information on North American species, and the work of Dr. Lynn Rogers. Some interesting sections including an excellent slide show about how dangerous are black bears?.Includes pages with black bear sounds.
Bears.org	Some information on bears, including myths. Has a small section comparing black bears and grizzlies.
Bear Den	Great overall site about bears. Multimedia bear information centre for grizzly and brown bears, polar bears, panda bears, black bears, asiatic bears, spectacled bears, sun bears and sloth bears.
American Bear Advisory Group	American Zoo and Aquarium Association. A second site for Don Middleton's Bear Den, with a diffeerent focus and some different information.

Grizzly Bears

Grizzly Bear Conservation Strategy	British Columbia Ministry of Environment, Lands, and Parks. A site with general and specific information on the grizzly bear including data on biology, distribution, diets, etc. Also included is a downloadable bibliography of papers on the grizzly bear.
Grizz Ed	Information on the Grizz Ed Environmental Education Program Teachers can view an annotated bibliography of non-fiction books about bears.
Eastern Slopes Grizzly Bear Project	Responding to an urgent need for quality information about grizzly bear habitat use, responses to human land use and grizzly bear mortality. A valuable site for study, it includes an entire section on grizzly bear biology.
250 Grizzly Bears in Yellowstone	1997 article about grizzly bears in Yellowstone Park.
Yellowstone Grizzly Foundation	A conservation organization dedicated to grizzly bear conservation. includes some basic grizzly bear biology information.
Nature: Showdown at Grizzly River	Visit Alaska's McNeil River Falls which is teeming with salmon and grizzlies, and read about the growing pains of bear cubs. This site from the Public Broadcasting System is a good companion to the video: A River of Bears.
Nature: Walking With Giants: The Grizzlies of Siberia	What happens when a pair of naturalists move in to a remote cabin in the Siberian wilderness? They end up raising three orphaned bear cubs, of course! This site is a companion to the "Walking With Giants Nature program video, featuring Canadian biologist, Charlie Russell, and artist Maureen Enns. Remarkable adventures and thoughtful discussions about grizzly bear conservation and biology.
Wild Bearcam	Live from Alaska's McNeil River Sanctuary. From National Geographic. This site provides live images in the summer. Check between May and September. Also posted are video recordings of several behaviours.
Brown Bear Resources	Information about biology of grizzlies in Montana.
Yukon Grizzly	Information on biology of grizzly in the Yukon.

Polar Bears

Polar Bears - A SeaWorld Education Department Resource	A sumary of polar bear biology including information on the following: Scientific Classification;Habitat and Distribution; Physical Characteristics; Senses; Adaptations for an Aquatic Environment; Behavior; Diet and Eating Habits; Reproducation; Birth and Care of Young; Communication; Longevity and Causes of Death; Conservation; and, References and Bibliography.
The Polar Bear Home Page	This site summarizes the research activites of Dr. Malcolm Ramsay a faculty member of The Department of Biology at the University of Saskatchewan. Includes a scientific study on play fighting in male polar bears.
Polar Bears - Bear Den	Life-span, hibernation, cubs, and other aspects of polar bears outlined.
Polar Bears Alive	A good site for information on polar bear biology. This is a conservation organization. Their web site includes facts about polar bears, a gallery of pictures, and conservation of the polar bear.
The shrinking polar bears	A CBC National Feature story on a scientific study of the effects of global warming on polar bear survival.

Black Bears

Black Bear Live WebCam	View a live black bear in its den! Plus information on Dr. Lynn Rogers, a scientists who has studied black bears for years. Includes bear sounds.
University of Minnesota - Black Bear Info	Range of useful information about black bears.
American Bear Association	" Promoting the Welfare of the Black Bear Through a Better Understanding"
Appalachian Bear Center	Rehabilitation of black bears.
Yukon Black Bears	Information on Yukon black bear biology.

Living With Bears, Safety In Bear Country

You Are In Bear Country	Parks Canada tips for safe camping and hiking in bear country.
The Bear Facts	Alberta Government Information on Alberta bears. Some material on bear biology, mainly about safety around bears.
Bear Etiquette	Information about backcountry bear safety. Contains some bear information links.
Alaska guidelines	Information on safety in bear country
Guidelines for Humans and Black Bears: How to Co-Exist	Black bears and grizzly bears are different! Learn the safety precautions for both bears.
Safety in Bear Country,	Bear Facts and Bear Encounter Stories
How to Live with Black Bears	How to protect your food and property, and what to do if a black bear visits.
Mark of the Grizzly	Accounts of recent bear attacks and the hard lessons learned