CHAPTER 9

Ecosystem Structure, Diversity, and Change

IN THIS CHAPTER

Summary: The world contains millions of diverse plant, animal, and insect organisms living together in complex interconnected ecosystems. A major change in one group has a ripple effect on the overall system, sometimes impacting thousands of species.

KEY IDEA

Keywords

- Ecosystem, biosphere, biome, sustainable use, endemic species, range, extinct, wetlands, hotspots, ecological niche, habitat, primary succession, secondary succession, gene pool, natural selection, adaptation

Biological Populations

The world's oceans make up 99% of the planet's biosphere and contain the greatest diversity of life. Even the most biologically rich tropical rain forests can't match the biodiversity (number of species) found in a coral reef community.

Rain forests, deserts, coral reefs, grasslands, and a rotting log are examples of ecosystems with specialized populations. Land-based ecosystems are known as *biomes* and are further classified by rainfall and climate. Table 9.1 lists different biomes and their characteristics. Marine or aquatic-based ecosystems are primarily described as freshwater or saltwater. The vertical depths and sunlight levels are illustrated for an ocean biome in Figure 9.1.

KEY IDEA

> An *ecosystem* is a complex community of plants, animals, and microorganisms linked by energy and nutrient flows that interact together and with their environment.

Table 9.1 The Earth's biomes have a variety of plant types and rainfall amounts.

BIOME	YEARLY RAINFALL/SOIL TYPE	PLANT LIFE
Tundra	<25 cm, permafrost soil	Small leafy plants
Deserts (hot and cold)	<25 cm, sandy, coarse soil	Cactus and other water storing plants
Chaparral (scrub forest)	50–75 cm (winter), shallow infertile soil	Small hard-leaved trees, scraggly shrubs
Conifer forest	20–60 cm, acidic soil	Waxy, needle-leaved trees (conifers)
Grasslands	10–60 cm, rich soil	Mat-forming grasses
Deciduous forest	70–250 cm, high organic composition soil	Hardwood trees
Tropical rainforest	200–400+ cm, low organic composition soil	Tall trees with associated vines, etc., adapted to low light

Because the oceans seemed limitless, it's hard to grasp pollution's heavy impact on plant and animal marine species and ecosystems. Within the last 30 years, population increases, new technology, increased seafood demand, and many other factors have impacted marine ecosystems in ways unknown 100 years ago. As the planet's population has now passed six billion, scientists, economists, policy makers, and the public are becoming increasingly aware of the strain on the oceans' natural ecosystems and resources.

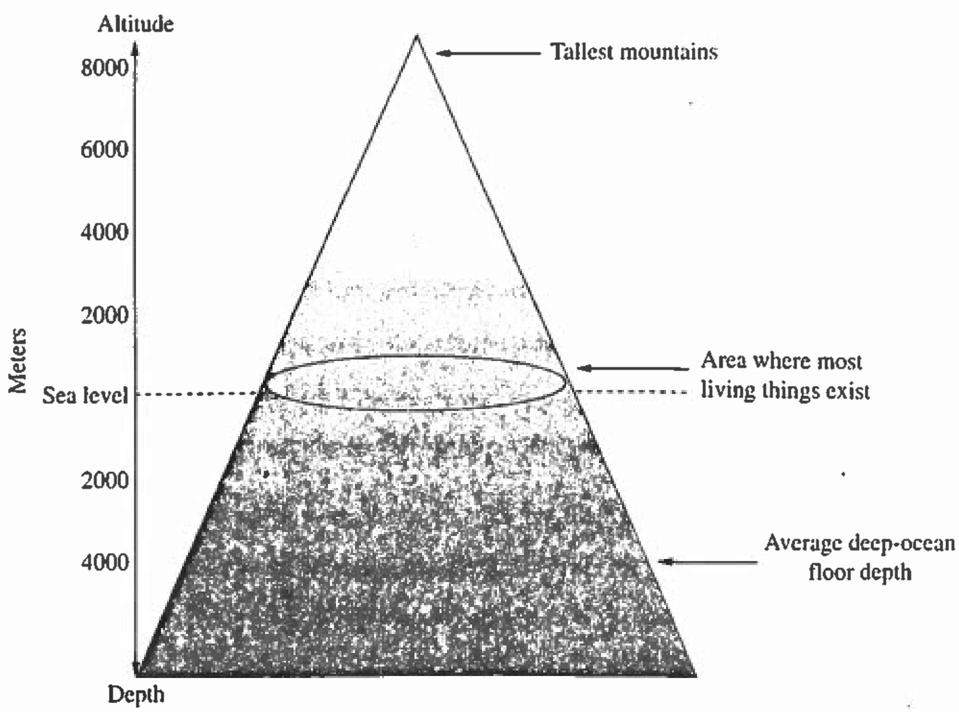

Figure 9.1 Most of the Earth's life is found in a small wedge.

Climate Change

The *Intergovernmental Panel on Climate Change* (IPCC) has gathered hundreds of scientists to examine the record-setting rise in global temperatures. A 2006 IPCC report stated with 90% certainty that the temperature rise seen in the past century is due to rising greenhouse gas in parts per million (ppm) and parts per billion (ppb) concentrations. From preindustrial times, carbon dioxide (2003; 280–380 ppm), methane (2005; 715–1,774 ppb), and nitrous oxide (2005; 270–320 ppb) have increased significantly. They act by absorbing infrared heat radiating from the Earth and heating the lower atmosphere. This atmospheric warming adds to natural greenhouse heating and causes even higher temperatures.

Changing climate temperatures impact coral reefs and forest ecosystems, along with related industries and jobs (lumber and fishing). Public policy in many countries has begun to address climate issues at the national, regional, and international levels. Conservation and sustainable biodiversity activities are becoming more common with a strong focus directed toward sustainable use.

KEY IDEA

> *Sustainable use* is the use of resources in a way that protects the numbers and complexity of a species or environment without causing long-term loss.

Some of the biologically diverse areas currently under study include marine, coastal, and inland waters; and island, forest, agricultural, as well as dry, subhumid, and mountain regions. Research programs addressing basic principles, key issues, potential output, timetables, and future goals of single and overlapping systems are being created.

Biosphere

The Earth system, which directly supports life, including the oceans, atmosphere, land, and soil, is called the *biosphere*. All the Earth's plants and animals live in this layer, which is measured from the ocean floor to the top of the atmosphere. All living things, large and small, are grouped into *species* or separate types. The main compounds of the biosphere contain carbon, hydrogen, and oxygen. These elements interact with other Earth systems.

KEY IDEA

> The *biosphere* includes the hydrosphere, crust, and atmosphere. It is located above the deeper layers of the Earth.

The biosphere is roughly 20,000 meters high. The portion most populated with living species is only a fraction of that. It is measured from just below the ocean's surface to about 1,000 meters above it. Most living plants and animals live in this narrow layer of the biosphere. Figure 9.1 gives an idea of the biosphere depth.

Biodiversity

The idea of a biologically diverse environment is easy to imagine in the middle of a tropical rain forest, but what about a desert? Sand, cactus, scrubby plants, and stunted trees don't seem to shelter much life, but they do. Diverse species are as uniquely suited to desert environments as those in the rain forest.

KEY IDEA

> *Biodiversity* is a measure of the number of different individuals, species, and ecosystems within an environment.

An animal or plant with a specific relationship to its habitat or other species, filled by it alone, occupies an *ecological niche.* Interrelationships between ecological niches make up a complex ecosystem. Whenever a major species overlap exists or a foreign species is introduced, the local balance is upset. A new natural balance must be gained for the ecosystem to work smoothly again.

If biodiversity is unbalanced and species eliminated, then niches must adjust. Some adjustments are minor, but more often a domino effect takes place with all members of the ecosystem rebalancing. The groups that can't change die out.

Species Evolution

TIP

A population's total genetic makeup is called its *gene pool.* When climate or habitat allows some individuals to live and reproduce while others die, the population is undergoing *natural selection.*

Species reach levels of specialization through *adaptation* (i.e., changing as the environment changes) and *evolution* (i.e., species' gene pools change over time). Organisms that adapt and reproduce in changing environments are said to have *evolutionary fitness.*

Genetic material in a cell's nucleus often changes during evolution. This comes from random protein breaks or other changes known as *genetic drift.* When a large percentage of a population dies from disease, starvation, or predation, the population's remaining genetic material is much reduced. The frequency of certain traits is also narrowed from the original population causing a *bottleneck effect.*

A different type of genetic drift happens when a few members of a population migrate and create a new population. Again, only a fraction of the original genetic material and its diversity is represented in the new group. This is known as a *founder effect.* When a species is transported to a completely new region, it is known as an *alien species.* Alien species often compete with local species for resources.

KEY IDEA

> The *Hardy-Weinberg principle* states that in a stable population, the frequency of genotypes and alleles (parts of genetic material) will remain constant.

TIP

A *species* is a group of intrabreeding organisms unable to interbreed with a different species. Over geological time, two groups of the same species may change (*macroevolution*) and eventually become so different they can no longer reproduce with each other. This is an example of *allopatric speciation* and often results from reproductive isolation. This happens in animal and plant species. *Sympatric speciation,* or the evolution of two different species from a single species, is more common in plants.

Species Interaction

Nearly all species are interconnected within an ecosystem. *Interspecific competition* occurs when two or more different species need the same habitat or resources to survive. When members of the same species need the same resources (e.g., finding a mate), it is known as *intraspecific competition.*

When two species compete and the stronger, better adapted species wins, the process is called *competitive exclusion.* When a species has no competitive limitations, it has a *fundamental niche.* When a species must settle for a smaller niche than it normally would have because of competition, the niche is called a *realized niche.*

> *Gause's principle* explains that no two species can fill the same niche at the same time, and the weaker species will fill a smaller niche, relocate, or die off.

Another type of interspecies competition, *predation,* occurs when one species serves as food for another species (e.g., rabbits for eagles). *Symbiosis* is the close, extended relationship between organisms of different species that may (↑) or may not (↓) benefit each participant. There are three types of symbiotic relationships to remember:

- *Mutualism.* Both species benefit (↑↑). (For example, lichen is a combination of a fungus and a photosynthetic algae or cyanobacterium. One adds structure and stores water, while the other creates organic compounds by photosynthesis.)
- *Commensalism.* One species is fairly unaffected (-) and one species benefits (↑). (For example, water buffalo and egrets have a commensalistic relationship because the egret eats insects from the buffalo's hide.)
- *Parasitism.* One species benefits (↑) and one species is harmed (↓). (For example, fleas are a parasite that live on dogs.)

Camouflage and *mimicry* are related competitive mechanisms. Many northern mammals (e.g., arctic hares) have coats that turn white in winter to blend with the snow, giving them protection or camouflage from predators. A walking stick is a brown, thin insect that looks just like a twig when clinging to a branch. It mimics its surroundings for protection.

Endemic Species

Plants and animals adapted to their environment are found worldwide. Some are widespread, while others are only found in a single river, lake, island, or mountain range. Organisms unique to a specific area are called *endemic species.*

Species like dogs and cats live in many habitats. Even in the wild, they are widely scattered. However, most species are limited to certain areas because their ecological requirements are only found in a small area. They might flourish in another region, but they aren't able to travel long distances or cross deserts to get there.

> *Endemic species,* naturally occurring in only one area or region, are unique to that specific region.

Polar bears aren't found in Arizona, because they are endemic to polar regions. Plants and animals needing warmer climates or a longer growing season are restricted by environmental conditions like temperature and rainfall. A species' geographical *range* often stretches across wide areas, depending on the environmental conditions. When their core habitat needs are met, they survive.

> The entire area that a plant, animal, insect, or other organism travels during its lifetime is considered its *range.*

The range of the once limitless American bison (millions of animals) has been reduced to a tiny fraction of what it once was. Range loss, and the massive slaughter that took place during the 19th century construction of the North American east–west railroad across their territory, took a heavy toll on the bison.

Keystone Species

A species around which an entire ecosystem is dependent, is known as a *keystone* or foundational species. Its controlling influence protects and balances many other species. For example, conservationists reintroduced wolves into Yellowstone Park in Wyoming to balance the nùmber of elk and other species, since without the predator they were outstretching regional resources.

Ecological Succession

Biological communities don't just suddenly spring up fully developed; there is a sequence of development. Over time, a previously untouched area like a volcanic flow will be populated by different species creating soil, cover, shade, and food resulting in a *primary succession* of development.

The first colonizers to a site (e.g., moss or lichens) are called *pioneer species.*

Secondary succession takes place when an existing community is disrupted by some event (e.g., wildfire, mining, or plowing) and must begin again. In both cases, the process of environmental modification by biological organisms is called *ecological development.* Less developed species gradually give way to more developed species as in the following succession example.

Rock ➡ lichen ➡ moss ➡ grasses ➡ bushes ➡ seedlings ➡ pine trees ➡ oak trees

When an ecosystem reaches its final stage of balanced species development, it is known as a *climax community.*

Habitat

The area in which an animal, plant, or microorganism lives and finds nutrients, water, sunlight, shelter, living space, and other essentials is called its *habitat.* Habitat loss, which includes the destruction, degradation, and fragmentation of habitats, is the primary cause of biodiversity loss.

Loss of habitat is perhaps the most important factor affecting a species. Think of when a tornado or hurricane levels a town. Not only are homes and businesses lost, but water supplies, food crops, communications, and transportation may also be annihilated. The area may become unlivable. Without the necessities required by humans to live or adapt to an environment, they must find a new place to live.

When a species is continually crowded out of its habitat by development or its habitat is divided and it can't reproduce, its numbers drop through *habitat fragmentation.* Adjacent habitats have overlapping boundaries called *ecotones* with higher species diversity and biological density than at a community's center. This increased diversity or *edge effect* allows some species to survive who couldn't live at the heart of the habitat. In fact, when ecotones are destroyed or changed, both edge and inner habit species are impacted.

When this happens, a species is said to be *endangered.*

> *Endangered species* are those species threatened with extinction (e.g., Florida panther and California condor).

Sometimes habitat loss is so severe or happens so quickly, it results in a species being eliminated from the planet. This happened to the dinosaurs. Scientists are still trying to decide what caused the mass extinction and there are a lot of theories, but except for in Hollywood movies, huge dinosaurs no longer roam the Earth.

> A species no longer living, anywhere on Earth, is said to be *extinct.*

Extinction takes place naturally, because for some species to succeed, others must fail. Since life began, about 99% of Earth's species have disappeared and, on several occasions, huge numbers have died out fairly quickly. The most recent of these mass extinctions, about 65 million years ago, swept away the dinosaurs and many other forms of life. Though not extinct as a result of human actions, the dinosaurs are a good example of a large number of species unable to adapt to environmental changes.

In the United States, conservation efforts were strengthened when the *Marine Mammals Protection Act* (1972), *Endangered Species Act* (1973), and *Convention on International Trade in Endangered Species of Wild Flora and Fauna* (CITES, 1973) were passed. These policies protected land and marine animals and made it a crime to hunt, capture, or sell species considered endangered or threatened.

Local extinction takes place when every member of a specific population in a specific area has died. Table 9.2 shows the number of species evaluated and those placed on the Endangered Species List by the World Conservation Union. For the past 40 years, the *World Conservation Union's Species Survival Commission* (SSC) has been ranking the conservation status of species, subspecies, varieties, and selected subpopulations worldwide, to pinpoint groups threatened with extinction. To promote their conservation efforts, the SSC has the most current, objective, scientifically based information on the status of globally threatened biodiversity available. The collected data on species rank and distribution gives policy makers solid information with which to make informed decisions on preserving biodiversity at all levels.

In 2010, the World Wildlife Fund's list included polar bears, tigers, leatherback turtles, monarch butterflies, giant pandas, rhinos, and bluefin tuna. A few species that have approached extinction or become completely extinct include the *Gorilla beringei beringei* (African mountain gorilla), *Pyrenean ibex* (European goat), *Canis rufus floridianus* (Florida wolf), and *Hippopotamus madagascariensis* (Madagascan hippo). Global extinction happens when every member of a species on the Earth has died. The passenger pigeon and the dodo are examples of globally extinct birds. Extinct is forever.

Wetlands

Wetlands provide the habitat for richly diverse populations. Once considered unimportant, wetlands are now known to support important and extensive ecosystems. Wetland plants convert sunlight into plant material or biomass and provide food to many different kinds

Table 9.2 Species are becoming endangered through habitat loss, pollution, and poaching.

	NUMBER OF SPECIES	NUMBER OF SPECIES EVALUATED (2010)	NUMBER OF THREATENED SPECIES (2010)
Mammals	5,416	4,863	1,094
Birds	9,956	9,956	1,217
Reptiles	8,240	1,385	304
Amphibians*	6,199	5,915	1,770
Fishes	30,000	3,119	800
Insects	950,000	1,255	559
Molluscs	81,000	2,212	974
Crustaceans	40,000	553	429
Corals	2,175	13	5
Others	130,200	83	42
Mosses	15,000	92	79
Ferns	13,025	211	139
Lichens	10,000	2	2
Mushrooms	16,000	1	1
Total	1,727,708	55,926	10,533

of aquatic and land animals, supporting the aquatic food chain. Wetlands, often protected, also provide moisture and nutrients needed by plants and animals alike.

KEY IDEA

> *Wetlands* are low, soggy places where land is constantly or seasonally soaked, or even partly underwater.

Wetlands, transitional areas between land and marine areas, can be swamps, bogs, peat lands, fens, marshes, or swamp forests. The water table is above, even with, or near the land's surface. Wetland soils hold large amounts of water and their plants are tolerant of occasional flooding.

About 60% of U.S. major commercial fisheries use estuaries and coastal marshes as nurseries or spawning sites. Migratory waterfowl and other birds also rely on wetlands for homes, stopovers, and food.

TIP

Wetlands are home to more than 600 animal species and 5,000 plant species. In the United States, nearly 50% of the species on the endangered animals list, and 25% of the plants, live in or rely upon wetlands. One-half of U.S. migratory birds are dependent on wetlands.

Internationally, wetlands are taking a hit as well. In Canada, which contains 25% of the world's wetlands, 15% of the wetlands have been lost. Germany and the Netherlands have lost over 50% of their wetlands.

Ocean Residents

Besides overfishing and introduction of alien marine species, there are environmental concerns for nearly every resident of the world's oceans. Everything from sharks, whales, and dolphins, to jellyfish, tube worms, and kelp beds has been impacted by ocean pollution. Since even the smallest members (microorganisms) of the food web are affected by chemicals, turbidity, and temperature increases, pollutants cause a domino effect as larger and larger species are impacted.

Hotspots

In 1988, British ecologist Norman Myers described the biodiversity hotspot idea. Although tropical rain forests have the highest extinction rates, they aren't the only places at risk. Myers pointed out a resource problem facing ecologists. They couldn't save everything at once and needed a way to identify areas with endangered species.

Globally, there are hundreds of species facing extinction because of habitat destruction and loss. Myers identified 18 high-priority areas where habitat cover had already been reduced to less than 10% of its original area or would be within 20 to 30 years. These regions make up only 0.5% of the Earth's land surface, but provide habitat for 20% of the world's plant species facing extinction.

TIP

Two factors weigh heavily in identifying a hotspot: (1) high diversity of endemic species and (2) significant habitat impact and alteration from human activities.

Plant diversity is the biological basis for hotspot designation. To qualify as a hotspot, a region must support 1,500 endemic plant species, of the total worldwide population. Existing natural vegetation is used to assess human impact in a region.

KEY IDEA

> An ecological region that has lost more than 70% of its original habitat is known as an environmental *hotspot.*

Since plants provide food and shelter for other species, they are used in rating an area as a hotspot. Commonly, the diversity of endemic birds, reptiles, and animals in hotspot areas is also extremely high. Hotspot animal species are found only within the boundaries of the hotspot, since they are often specifically adapted to endemic plant species as their main food source.

In hotspot designations by world conservation agencies, 25 biodiversity hotspots, containing 44% of all plant species in roughly 1.0% of the planet's land area, were listed. Hotspots target regions where the extinction threat is the greatest to the highest number of species. This allows biologists to focus cost-effective efforts on critical species.

Endemic species have been isolated over geological time. Islands, surrounded by water, have the most endemic species. In fact, many of the world's hotspots are islands. Topographically different areas like mountain ranges allow the greatest ecosystem diversity.

Several hotspots are tropical island archipelagos, like the Caribbean and the Philippines, or big islands, like New Caledonia. However, other hotspots are continental islands isolated by surrounding deserts, mountain ranges, and seas.

Peninsulas are key regions for hotspots. They are similar to islands and some, like Mesoamerica, Indo-Burma, and the Western Ghats in India, were islands at some time in the past. Other hotspots are landlocked islands isolated between high mountains and the sea. The Andes Mountains, which separate South America from north to south, are an impassible barrier to many species. On the western coast, the lowlands support a thin ecosystem, isolated from the eastern side of the continent.

The Cape Floristic Province in South Africa is isolated by the extreme dryness of the Kalahari, Karoo, and Namib deserts, and large rivers like the Zambezi and the Limpopo.

Why Are Hotspots Fragile?

TIP

Island ecosystems are particularly fragile because they are rarely exposed to outside influences. Ecologists have found that most extinct species were island species and not widely spread. They lived in specific isolated habitats. Once a one-of-a-kind population is gone, the species is lost forever.

Isolated species lose their defenses over time, because they are only exposed to a limited number of other species. When they have to compete with new, previously unknown species, they can't adapt fast enough. This is especially true if the new species is highly competitive and adaptable.

For example, large extinct birds like the *moa* and *dodo*, which had no predators on the remote Australian continent, lost their ability to fly. When humans and other predators arrived, they were easy targets and quickly dropped in numbers.

Since many global hotspots are beautiful and unique, humans have been drawn to their natural diversity throughout human history. Ecosystems and landscapes were changed, first by hunter-gatherers, then by farmers and herdsmen, and most extensively by the global growth and sale of agricultural crops. During the past 500 years, many species have been hunted to the last individual.

Currently, growing human populations in world hotspots add to species' decline by the introduction of nonnative species, illegal trade in endangered species, industrial logging, slash and burn agricultural practices, mining, and the construction of highways, dams, and oil wells. Eleven hotspots have lost at least 90% of their original natural vegetation, and three of these have lost 95%.

TIP

Today, the world's regions considered the "hottest of the hot spots" are Madagascar and the Indian Ocean islands, the Philippines, Sundaland, the Atlantic Forest, and the Caribbean. These five hotspots have the most unique biodiversity and are at extreme risk of losing it without immediate and effective conservation.

Conservation

Since hotspots have the highest concentrations of unique biodiversity on the planet, they are also at the greatest risk. We must preserve hotspot species to prevent a domino effect of ecosystem extinction. Knowledge and tools to protect hotspots must be in place, as well as ongoing updates of political, social, and biological conditions associated with hotspots.

Information on hotspot species is being collected, and biological evaluations made in little-understood land, freshwater, and ocean ecosystems. Teams of international and regional biologists are performing hotspot assessments. Field station networks of all the world's main tropical areas are being set up to monitor biodiversity.

Solutions

Different conservation methods are important to protect hotspot biodiversity. These vary from the creation of protected areas to alternatives like ecotourism. Educating people at the local and national levels is also important. Governmental policies and awareness programs, with improved business practices to protect against ongoing biodiversity loss, are critical.

Strengthening existing conservation efforts lessens potential climate destabilization and offers greater resilience against weather disasters that threaten both people and habitat.

Creating protected areas and conservation regions, and improving the administration of over 55 million acres of parks and protected areas in hotspots and wilderness areas are crucial to ensuring continued biodiversity.

Species' habitat ranges adjust to climate change, which impacts ecologists' ability to protect them in existing parks. Range boundary shifts due to temperature increases have been taking place for over 75 years. To lower extinction risks connected with global warming, conservation methods must be developed to address this problem.

Many medicines come from plants and fungi. New species in today's hotspots may hold the key to research and treatments for human disorders like emphysema and cancer. It is important to protect these valuable resources. However, conserving biodiversity in hotspots worldwide is not an easy job. No one country or organization can do it alone. Everyone has to work together. As the world's population continues to climb, environmental issues will become critical for more and more species, including our own.

Remote Sensing

When environmentalists make observations, take measurements directly, or collect samples, it's called *in situ* data collection or *field sampling.* Field sample collection and analysis are done at a sample site, but when too many people take samples from the same place, the area can get stomped down and disturbed. This is why national parks and forests ask people to stay on trails. They want to protect pristine areas.

When scientists study an area and want to avoid disturbing the environment, they use remote sensing instruments aboard aircraft, high-altitude balloons, and satellites. Much of this technology was developed as stealth imaging during war time or for space exploration by NASA. The environmental benefits from this cutting-edge technology make it possible to accurately image an object or environment to within a meter.

> The measurement or study of an object, area, or event by a distant recording device is known as *remote sensing.*

The *Advanced Spaceborne Thermal Emission and Reflection Radiometer* (ASTER) is a remote sensing instrument. It is located aboard *Terra,* a satellite launched in 1999 as part of NASA's *Earth Observing System* (EOS). ASTER is a joint project between NASA; the Japanese Ministry of Economy, Trade, and Industry; and the Earth Remote Sensing Data Analysis Center. ASTER data are used to draw detailed maps of land surface temperature, reflectance, and elevation.

Different remote sensing instruments can gather information about temperature, chemistry, photosynthetic ability, moisture content, and location. Table 9.3 shows some of the geographical and ecological characteristics that can be observed with remote sensing.

Habitat hotspots can also be observed with satellite imagery and aerial photography. For example, moisture information helps track changes in vegetation over time. Sensors record electromagnetic energy from vegetation without having to collect samples. When analysis is needed, scientists use remote sensing to direct them to problem areas so that samples of affected plants and trees can be taken.

Maps can be made of images taken at different times. These maps help scientists and policy makers by showing deforestation and habitat loss, as well as other biodiversity threats, such as forest fires, illegal logging, and construction development.

Table 9.3 Important land and water characteristics can be determined by remote sensing.

BIOLOGICAL AND PHYSICAL CHARACTERISTICS	REMOTE SENSING SYSTEMS
x, *y* Location	Aerial photography, Landsat, SPOT HRV, Space Imaging IKONOS, ASTER, Radarsat, ERS-1,2 microwave, ATLAS
z Topographic/depth measurement	Aerial photography, TM, SPOT, IKONOS, ASTER, Radarsat, LIDAR systems, ETM
Vegetation (*chlorophyll concentrations, biomass, water content, absorbed photosynthetic radiation, phytoplankton*)	Aerial photography, TM, SPOT, IKONOS, ETM, Radarsat, TM Mid-IR, SeaWiFS, AVHRR, IRS-1CD
Surface temperature	GOES, SeaWiFS, AVHRR, TM, Daedalus, ATLAS, ETM, ASTER
Soil moisture	ALMAZ, TM, ERS-1,2 Radarsat, Intemap Star 3i, IKONOS, ASTER
Evapotranspiration	AVHRR, TM, SPOT, CASI, ETM, MODIS, ASTER
Atmosphere (*chemistry, temperature, water vapor, wind speed/direction, energy input, precipitation, clouds, and particulates*)	GOES, UARS, ATREM, MODIS, MISR, CERES
Reflectance	MODIS, MISR, CERES
Ocean (*color, biochemistry, phytoplankton, depth*)	POPEX/POSEIDON, Sea WiFS, ETM, IKONOS, MODIS, MISR, ASTER, CERES
Snow and sea ice (*distribution and characteristics*)	Aerial photography, AVHRR, TM, SPOT, Radarsat, SeaWiFS, ICONOS, ETM, MODIS, ASTER
Volcanoes (*temperature, gases, eruption characteristics*)	ATLAS, MODIS, MISR, ASTER
Land use	Aerial photography, AVHRR, TM, SPOT, IRS-ICD, Radarsat, Star 3i, IKONOS, MODIS

*In part from Jensen, John R., 2007, *Remote Sensing of the Environment: An Earth Resource Perspective*, 2nd Ed., Upper Saddle River, NJ: Prentice Hall.

> Review Questions

Multiple-Choice Questions

1. A complex community of plants, animals, and microorganisms linked by interacting energy and nutrient flows is called a(n)

   (A) atmosphere
   (B) ecosystem
   (C) niche
   (D) suburb
   (E) species

2. The world's oceans make up what percent of the planet's biosphere?

   (A) 27%
   (B) 44%
   (C) 62%
   (D) 75%
   (E) 99%

3. Which diverse ecosystem absorbs high flow and releases water slowly?

   (A) High plains
   (B) Wetlands
   (C) Arctic
   (D) Rocky Mountains
   (E) Old-growth forest

4. Madagascar and the Indian Ocean islands, the Philippines, Sundaland, the Atlantic Forest, and the Caribbean are all considered

   (A) hotspots
   (B) expensive vacation spots
   (C) sustainable use areas
   (D) arid regions
   (E) mountainous

5. Aircraft, high-altitude balloons, and satellites are all used in

   (A) birthday parties
   (B) field testing
   (C) remote sensing
   (D) acrobatic air shows
   (E) high school science labs

6. The vertical range that contains the biosphere is roughly

   (A) 1,000 meters high
   (B) 5,000 meters high
   (C) 10,000 meters high
   (D) 20,000 meters high
   (E) 40,000 meters high

7. When a species like the dodo bird becomes extinct, it is said to be

   (A) in remission
   (B) hibernating for the winter
   (C) not important to the ecosystem
   (D) gone for 10 years and then returns
   (E) gone forever

8. The total area in which a plant, animal, insect, or other organism travels in its lifetime determines its

   (A) life span
   (B) range
   (C) personality type
   (D) itinerary
   (E) habitat

9. ASTER information is used to draw detailed maps of land surface temperature, elevation, and

   (A) salt flats
   (B) mountain algae populations
   (C) reflectance
   (D) honeybee populations
   (E) shipping lanes

10. Adjacent habitats have overlapping boundaries called

    (A) wetlands
    (B) topography
    (C) ecological succession
    (D) ecotones
    (E) secondary succession

11. Over time, a previously untouched area like a volcanic flow will be populated by different species creating soil, cover, shade, and food resulting in a(n)

(A) primary succession of development
(B) secondary succession of development
(C) tertiary succession of development
(D) overcrowded ecosystem
(E) ecotone

12. A hotspot is an ecological region that has lost

(A) 10% of its original habitat
(B) 20% of its original habitat
(C) 45% of its original habitat
(D) 60% of its original habitat
(E) over 70% of its original habitat

13. The most important factor currently affecting many species is

(A) loss of habitat
(B) predation
(C) food supply
(D) climate
(E) disease

14. The use of resources in a manner which protects a species or environment without causing long-term loss is known as

(A) evolutionary use
(B) clear cutting
(C) sustainable use
(D) extinction
(E) speciation

15. When no two species can fill the same niche at the same time and the weaker species must fill a smaller niche, relocate, or die, it is known as

(A) survival of the fittest
(B) Gause's principle
(C) the conservation of species
(D) a keystone species
(E) climax succession

16. When a species' numbers drop continuously because of habitat destruction, the species is said to be

(A) extinct
(B) poor predators
(C) protected
(D) not evolutionarily hearty
(E) endangered

17. Mutualism is a type of symbiosis where

(A) neither species benefits
(B) both species benefit
(C) one species benefits and one is unaffected
(D) one species is harmed and one benefits
(E) both species are harmed

18. When a species has no competitive limitations, it has a

(A) realized niche
(B) developed niche
(C) fundamental niche
(D) successive niche
(E) population overshoot

19. When an ecosystem reaches its final stage of balanced species development, it is called a(n)

(A) climax community
(B) population
(C) pioneer species
(D) initial niche
(E) extinct zone