MODULE 2: HUMAN IMPACTS ON BIODIVERSITY

Learning Objectives

Students will be able to:

- Identify direct and indirect anthropogenic (human-caused) threats to biodiversity.

Key Topics

- Drivers of Human Impacts on Biodiversity
- Habitat destruction
- Hunting
- Overexploitation
- Invasive species and disease
- Wildlife Diseases
- Pollution
- Climate Change

Humans dominate the planet to an extent never before seen. Our rapidly expanding populations and economies place staggering demands on the world's limited resources. To meet these needs, one-third to one-half of the planet's land surface has been substantially altered by human activity. Many species barely manage to survive on a fraction of their former range and in increasingly fragmented landscapes. Ecosystems, such as tropical dry forests and grasslands, have almost completely disappeared from our planet, taken over for agriculture. Dams disrupt freshwater ecosystems, while overfishing, pollution, and habitat destruction threaten the marine world. Humans are also transporting plants and animals around the globe both deliberately and unintentionally. These "invaders" threaten other species or change entire ecosystems. Our planet is increasingly made up of species that can only survive in human-modified landscapes. Human influence reaches the farthest corners of the globe: the Arctic and Antarctic are contaminated by pollutants created tens of thousands of kilometers away and carried through the atmosphere. We are even changing the earth's atmosphere through the industrial release of carbon dioxide, which may dramatically change the earth's climate, and diminishing the ozone layer through the production of chlorofluorocarbons.

- **Drivers of Human Impacts**

READING: Nelson et al (2006), "Anthropogenic drivers of ecosystem change"

A **driver** is any natural or human-induced factor that directly or indirectly causes a change in an ecosystem. A direct driver unequivocally influences ecosystem processes. An indirect driver operates more diffusely, by altering one or more direct drivers.

Direct or indirect actions by humans have resulted in the decrease of biodiversity. The Convention of Biological Diversity states that there are both indirect and direct human drivers. Some of the indirect human drivers are demographic, economic, sociopolitical, scientific and technological, and cultural and religious factors. Some of the direct human drivers are changes in local land use and land cover, species introductions or removals, external inputs, harvesting, air and water pollution, and climate change.

Changes in biodiversity and in ecosystems are almost always caused by multiple, interacting drivers. Changes are driven by combinations of drivers that work over time (such as population and income growth interacting with technological advances that lead to climate change) or level of organization (such as local zoning laws versus international environmental treaties) and that happen intermittently (such as droughts, wars, and economic crises).

  - Habitat destruction
- Habitat loss and degradation

Ecosystem loss and fragmentation is the greatest worldwide threat to biodiversity and the primary cause of species extinction. Ecosystem loss and fragmentation are related processes and typically occur simultaneously.

Ecosystem loss refers to the disappearance of an ecosystem, or an assemblage of organisms and the physical environment in which they exchange energy and matter. Many studies, however, examine loss with respect to a specific organism's habitat. **Habitat loss** is the modification of an organism's environment to the extent that the qualities of the environment no longer support its survival. Habitat loss usually begins as **habitat degradation**, the process where the quality of a species' habitat declines. Once the habitat's quality has become so low that it no longer supports that species then it is termed habitat loss.

- Pollution
- Deforestation
- logging
- agricultural conversion

READING: Maxwell et al (2016), "The Ravages of Guns, Nets, and Bulldozers"

The world's forests began declining thousands of years ago, with the expansion of farming and herding in the Middle East and Europe. More recently, rapid population growth, industrialization, and globalization are contributing to rapid deforestation in many tropical regions. While there is no question that forest loss and fragmentation is substantial, determining the exact rate of these losses globally is complex. Depending on how "forest" is defined, what forest cover data is presented, or how it is analyzed, the picture we obtain may end up being quite different; for example, by changing the time periods used in an analysis, deforestation rates may differ dramatically. According to estimates from the Tropical Ecosystem Environment Observation by Satellite (TREES), between 1990 and 1997, 5.8 million hectares of humid forest were lost each year, which corresponds to a rate of 0.52% per year. A further 2.3 million hectares were obviously degraded, a rate of 0.20% a year.

Causes of deforestation

Rainforests cover less than two percent of the Earth's surface, yet they are home to some 40 to 50 percent of all life forms on our planet - as many as 30 million species of plants, animals and insects. The rainforests are the oldest, richest, most productive and most complex terrestrial ecosystems (complexes of a community of organisms and their environment functioning as an ecological unit) on Earth.

Yet, in spite of decades of efforts to curtail and reduce selective and large-scale removal of tree species, deforestation—the removal of trees from a forested site and the conversion of land to another use, most often agriculture—has only worsened. Deforestation is primarily confined to developing countries, and mainly in the tropics. Shrinking areas of tropical forests have been gradually arousing increasing anxiety over land management with both economic and environmental consequences. The livelihood of over two hundred million forest dwellers and settlers depend directly on food, fiber, fodder, fuel and other resources taken from the forest or produced on recently cleared forest soils. Indeed, tropical deforestation has become an issue of global environmental concern, in particular because of the value of tropical forests in biodiversity conservation and limiting the greenhouse effect.

Effects of deforestation can be observed at all scales of the rainforest ecosystems: local, regional, and global. From a biodiversity perspective, local effects of clear-cutting include loss of habitat. Other direct local environmental effects are soil nutrient depletion and erosion, increased runoff, sedimentation, and indirectly, pollution, and compaction of soil due to hoof action of livestock. Selective logging (exploitation of largest, highest quality trees requiring little or no silvicultural skill) does not provide for regulated sustained yield and often results in overstocked stands.

Introduction and proliferation of transportation routes, utility grids, and land parcels lead to a regional phenomenon called land fragmentation. That is, clearing of tropical forests creates a highly-modified landscape where remnant patches of native flora are set in a matrix of agricultural lands and urban-residential development. Loss of biodiversity in the tropics is directly related to forest clearing and a subsequent decrease of total habitat area. Fragmentation also causes remnant vegetation patches to be situated in different positions in the landscape, varying in size, shape, isolation, and time since excision from the continuous forest. These factors, in turn, negatively influence the biodiversity of a fragment, "and in a complex manner, the biodiversity of the collection of fragments that occupies the landscape.”. Smaller stands may also threaten certain species with narrow habitat requirements and reveal structural changes underlying large-scale forest fragmentation in highly altered landscapes.

Values of global significance are increasingly being attributed to tropical forests. One such attribute is their ability to accumulate atmospheric carbon, in other words, to function as a carbon 'sink'. Carbon dioxide is one of the most important greenhouse gases and is responsible for about 60 percent of the enhanced greenhouse warming. Deforestation on a global scale has greatly contributed to the total release of carbon into the atmosphere and some estimates put deforestation at a quarter of the total contribution of carbon dioxide. It is generally agreed that deforestation also has likely effects on the global hydrological cycle and global climatic change.

Two main forces cause deforestation:

- Competition between humans and other species for the remaining ecological niches on land and in coastal regions. This factor is substantially demonstrated by the conversion of forestland to other uses such as agriculture, infrastructure for transportation and utilities, urban development, industry.

- Failures in the workings of the economic systems to reflect the true value of the environment. Many of the functions of tropical forests are not marketed and, as such, are ignored in decision-making. Additionally, decisions to convert tropical forests are themselves encouraged by fiscal and other incentives.

Factors that stimulate production and profits such as increased agricultural output prices, decreased input prices and increased flow of technology into agriculture, have a negative effect on the tropical forests that are consequently converted to agricultural uses.

READING: Vijay et al, "Impacts of Oil Palm on Recent Deforestation and Biodiversity Loss"

Additionally, the lack of respect for traditional land rights, and other institutional incentives that complicate property rights to forestland, encourage short-term exploitation of forests rather than long-term sustainable use. In the case of tropical forests, the benefits of preservation of biodiversity and the value of the genetic pool in developing new medicines, crops, and pest control agents are poorly reflected in market allocations. These seemingly implicit benefits provide services that extend far beyond the borders of the host country, which has little incentive to implement globally efficient policies. Thus, the prevailing configuration of markets and policies leaves the forests outside the domain of markets, unowned, unpriced and unaccounted for. Furthermore, this configuration might foster their excessive use and destruction despite their growing true immeasurable and universal values.

- Habitat fragmentation and edge effects

Fragmentation is a product of ecosystem loss and can be thought of as the division of a formerly contiguous landscape into smaller units. Ultimately, fragmentation reduces continuity and interferes with species dispersal and migration, thereby isolating populations and disrupting the flow of individual plants and animals (and their genetic material) across a landscape.

A **patch** is defined by its area, perimeter, shape, and composition (e.g., a land cover type, such as water, forest, or grassland, a soil type, or other variable).

Habitat loss and fragmentation are related and usually occur in conjunction. These processes are impacting all of Earth's environments, both terrestrial and aquatic, albeit in different ways. Fragmentation can occur due to natural causes but is increasing dramatically due to human activity. Consequences include **decreased habitat size**, **negative edge effects**, and **isolation of sub-populations**. Managers must consider fragmentation when considering conservation plans.

Fragmentation is caused by both natural forces and human activities, each acting over various time frames and spatial scales.

Fragmentation due to Natural Causes

1. Over long time frames (thousands or millions of years), landscapes are fragmented by geological forces (e.g., continental drift) and climate change (e.g., glaciations, changes in rainfall, sea level rise).
2. Over short periods (decades or months), natural disturbances, such as forest fires, volcanoes, floods, landslides, windstorms, tornadoes, hurricanes, and earthquakes, modify and fragment landscapes.

In addition, landscapes are naturally fragmented by mountain ridges, canyons, rivers, and lakes. Also, some ecosystems commonly occur in discrete patches and are thus naturally fragmented. Natural processes create the habitat heterogeneity and landscape diversity upon which many species depend.

Fragmentation due to Human Activity
Humans have modified landscapes for thousands of years. Early hunters influenced the landscape by burning areas to favor certain game species, and today ranchers keep grasslands open in the same way. Many human activities – agriculture, settlement (e.g., construction of buildings, fences, etc.), resource extraction (e.g., mining, timber), industrial development (e.g. the construction of hydroelectric dams – alter and fragment landscapes. Of these activities, agriculture is the leading cause of ecosystem loss and fragmentation throughout much of the world today.

The process of human-caused fragmentation often proceeds in a fairly predictable manner. First, an opening is formed in a matrix of natural habitats – perhaps a road is built that crosses the landscape. This opening becomes larger as settlement and deforestation occur along the road. Still, the landscape remains largely forested and although there is habitat loss, fragmentation is minimal. Second, smaller roads are constructed off the main road, increasing access to the forest. The newly accessed areas are subsequently cleared for crops. The landscape begins to appear fragmented, even though the remaining patches of original forest are still large. This process of subdivision repeats itself at a finer and finer scale until the landscape shifts to one predominated by cleared or degraded land, with patches of isolated forest. Eventually, all of the landscape may be converted for human use, except those spots that are too wet, too dry, or too steep to be useable.

Humans also create distinctive patterns as they fragment landscapes, typically leaving patches that are non-random in size and distribution. Clearing by peasant farmers, in some cases planned and in others not, leaves a complex mosaic of cropland, secondary forest, and forest remnants.

There are several technical terms commonly used in the field of landscape ecology to define different stages of the fragmentation process or different forms of fragmentation of a landscape. These include perforation (holes punched in a landscape), dissection (initial subdivision of a continuous landscape), fragmentation (breaking into smaller parts), shrinkage (reduction in size of patches), and attrition (loss of patches).

Natural versus Human Fragmentation
Several differences exist between human-caused and naturally fragmented landscapes.

1. A naturally patchy landscape often has a complex structure with many different types of patches. A human-fragmented landscape tends to have a simplified patch structure with more distinct edges, often with a few small patches of natural habitats in a large area of developed land.
2. Patch types in human-modified landscapes are often unsuitable to many species, while in a heterogeneous natural landscape most patch types are suitable to a more diverse group of species.
3. The borders (or edges) of patches in naturally patchy landscapes tend to be less abrupt than in those created by humans (Edge effects are discussed in detail later in this document).

Certain features of human-fragmented landscapes, such as roads, are novel in the evolutionary history of most wild species and pose additional threats. Not only do they restrict movement between populations, but heavily traveled roads are also a direct danger to wildlife. Furthermore, some animals avoid habitats near roads due to noise pollution. Roads also have secondary impacts on ecosystems and species. They are an access point, increasing a region's vulnerability to invasion by exotic species, and perhaps most importantly, making wildlife habitats accessible to people for hunting or resource extraction. In West Africa, for example, new roads for logging act as conduits for the bushmeat trade, which has contributed to the extirpation of many duiker species (Cephalopus spp.) and the extinction of at least one primate species, Miss Waldron's red colobus monkey (Procolobus badius waldroni).

- Effects of Fragmentation

Fragmentation and loss of ecosystems are coupled processes; fragmentation is a consequence of loss. It is often difficult to distinguish between the effects of these two processes, since they often happen simultaneously. Loss of habitat impacts species principally by reducing available resources and microenvironments. Fragmentation has additional consequences for species on top of those caused by loss – most importantly, affecting movement and dispersal and modifying behavior. As fragmentation progresses in a landscape, three major consequences are apparent (1) decreasing patch size; (2) increased edge effects; and (3) increased patch isolation.

Decreasing Patch Size
Once a landscape has been fragmented, the size of the remaining patches is a critical factor in determining the number and type of species that can survive within them. For all species – large or small – that cannot or will not cross a forest edge or leave a patch, all requirements to complete their life cycle must be met within the patch, from finding food to mates. This is especially important for species with complex life cycles, each with distinct habitat requirements. For example, many amphibian species have an aquatic larval stage and an upland adult phase. Also, some species require large areas of continuous habitat and cannot survive in small patches – they are referred to as area-sensitive species. Furthermore, large patches typically support larger populations of a given species and thereby buffer them against extinction, inbreeding depression, and genetic drift.

Increased Edge Effects
One of the most obvious changes to a fragmented landscape is the increase in edge environment. Edge environments or ecotones mark the transition between two different habitats. In a naturally forested landscape, edge is usually limited to a small area, such as along streams or landslides. Natural edges are usually less abrupt than human-formed edges and show a gradual transition from one habitat type to another. Along agricultural frontiers, the original landscape may be fragmented into long narrow strips or shreds, interspersed with areas of agriculture. These strips may separate different crops, thus serving as windbreaks, or the boundary between two landowners. As a result, this remaining fragment is entirely made up of edge environment. Residual trees along rivers provide another example of narrow, edge-dominated environments.

The extent of edge environment in a fragment patch is determined in part by its shape. The ratio of the perimeter to area (or the amount of edge environment to the amount of interior) is one measure of patch shape. A circular patch has the maximum area per unit edge and will have less edge environment and fewer edge effects than a rectangular patch of the same size. Because edge effects may extend 200 meters (and sometimes more), small patches may be entirely composed of edge environment. For example, a new reserve is being created with an area of one square km. The reserve can either be rectangular: Reserve A (2 km by 0.5 m), or square: Reserve B (1 km by 1 km). As illustrated, both have the same total area but Reserve A will be composed entirely of edge environment and its core size will be 0 square km, whereas Reserve B will have a core area of 0.25 square km.

Fragmentation is a dynamic process, often with delayed effects; knowing the amount of time a patch has been isolated is critical to understanding the consequences of fragmentation. In long-lived species, such as trees, it may take a hundred years to observe the impact of fragmentation. Individual trees continue to survive immediately following fragmentation; however, they may no longer reproduce – perhaps they are too spread apart to exchange pollen by wind, or their pollinators or seed dispersers have disappeared.

The effects of fragmentation also vary depending on the cause of fragmentation (for example, fragmentation for agriculture versus for logging). It is difficult to make generalizations about the effects of a specific type of fragmentation on a particular landscape, since the consequences may be very different in a temperate versus a tropical region or in a grassland versus a forest, largely because the plants and animals present have different sensitivities to fragmentation.

Fragmentation's impact on species abundance, richness, and density is complex, and there is no clear rule what these effects may be. Studies of the effects of fragmentation on species abundance, richness, or density relative to fragment size have had inconsistent results, some indicating an increase in species, in others, a decline. However, it is important to keep in mind that simply counting the number of species does not measure impacts of fragmentation on behavior, dispersal ability, or genetic diversity.

Some species respond positively to fragmentation. Fragmentation may increase species richness by allowing generalist species to invade. Immediately following fragmentation, the density of individuals may increase as animals "crowd" into the remaining forest. This inflation of density will ultimately prove short-lived because patches are rarely adequate to support the same population density as more extensive habitats. This phenomenon underscores the need to monitor fragmentation effects over long time scales.

- Edge effects

Edge effects is a general term used to describe a number of different impacts, and can be categorized into several types: physical (e.g., microclimatic changes), direct biological (changes in species composition, abundance, and distribution), and indirect biological (changes in species interactions such as predation, competition, pollination, and seed dispersal). Moreover, many of the effects of fragmentation are synergistic; for example, fragmentation can lead to increased fire risk, increased vulnerability to invasive species, or increase hunting pressure.

Some of the most significant edge effects are the microclimatic changes that take place along a fragment's edge. Edge areas in forests are typically warmer, more exposed to light and wind, and drier than interior areas. Microclimatic changes along edges often have secondary effects, such as altering vegetation structure and eventually, plant and animal communities.

Increased wind along the edge of fragments physically damages trees, causing stunted growth or tree falls. This is especially obvious when a fragment first forms, since interior plant species are often not structurally adapted to handle high wind stress. Furthermore, wind tends to dry out the soil, decrease air humidity, and increase water loss (evapotranspiration rates) from leaf surfaces, creating a drier microclimate. This drier environment has a higher fire risk.

Edge effects - biological
The creation of "edge" following fragmentation causes a number of biological changes. These changes are often similar or coupled to the biological changes that result from the creation of the fragment itself. These include changes in species composition, abundance, and distribution, as well as changes in species interactions such as predation, competition, pollination and seed dispersal. Along the edge of a fragment, biological changes may extend farther than the physical ones.

Invasion by generalist species
Edges are more susceptible to invasion by generalist or "weedy" species that are better adapted to handle disturbance and the new microclimate. These species might be plants (such as lianas, vines, creepers, and exotic weeds), animals, or diseases. Simultaneously, long-lived interior canopy species, epiphytes, and other mature forest taxa decline in abundance. Wind along edges also increases the transfer of seeds from outlying areas, thereby aiding invasion of foreign, generalist, or weedy species. Introduction of animals, adapted to disturbed environments and human presence, such as domestic cats, rats, and mice, is often a problem along edges. As is disease transmission between wildlife and domestic animals.

Alteration of plant communities
The increased light along edges affects both the rate and type of plant growth, favoring fast-growing light-loving species at the expense of slower-growing shade-loving ones (Harper 2005). Studies of forest fragments in the Amazon noted a dramatic loss of plant biomass overall; although secondary vegetation (especially vines and lianas) proliferated, this new biomass did not compensate for the loss of "interior" tree species. Since many tree species have long life spans, it is important to examine the changes in plant communities over extended periods. It may take hundreds of years for the full consequences of fragmentation to be revealed.

Alteration of insect communities and nutrient cycling
Fragmentation alters both the abundance and composition of insect communities, thus affecting leaf litter decomposition and hence nutrient cycling.

- Isolation Effects

Barriers to Dispersal

The degree of isolation of a patch helps determine what biological communities it can sustain. While patches may appear isolated, their actual biological connectivity depends on the habitat that separates them. In fragmented landscapes, patches of high-quality habitat are typically interspersed with areas of poor habitat. In a very isolated patch, species that cannot disperse may be unable to find adequate resources or mates. They may become separated from other populations and thus prone to genetic inbreeding and possibly local extinction.

Species response to isolation

A species' response to fragmentation depends on its dispersal ability as well as its perception of the environment. For example, species that fly (e.g., birds, bats, flying insects) are typically less affected by patch isolation than less mobile species (e.g. frogs and beetles). For some species, crossing an open field for two kilometers is not a problem. However, species that spend most of their times in treetops (e.g., some species of primates and marsupials) or in dark, interior forest may never cross such a large opening. A species that disperses over long distances, such as an African elephant (Loxodonta sp.), will perceive a particular landscape as more connected than a species with short-range dispersal, such as a shrew (species of the family *Soricidae*).

- Vulnerability to Fragmentation

Large-bodied vertebrates, especially those at high trophic levels, are particularly susceptible to habitat loss and fragmentation, and are among the first species to disappear. Thus, predators are often lost before their prey, and those species that do survive on small fragments (usually herbivores) tend to become far more abundant than populations of the same species on larger species-rich fragments. There are two principal explanations for this increased abundance. First, when competing species are removed, the resources they utilized become available to the persisting species. Second lack of predators in small fragments can also lead to an overabundance of herbivores that tend to weed out palatable plant species and convert the landscape into a forest of "herbivore-proof" plants. Furthermore, as large predators disappear, smaller predators often increase.

Fragmentation often alters animal behavior, due to changes in the environment or predator activity. Fragmentation can also take an indirect toll on plants whose pollinators or seed dispersers are forced to navigate an increasingly fragmented landscape in search of their host plants. Fragmentation triggers distortions in ecological interactions that drive a process of species loss, the end point of which is a greatly simplified ecological system lacking much of the initial diversity. Overall a combination of landscape type and structure, predator community, and level of parasitism are important in anticipating the outcomes of fragmentation.

Box 3. Identifying species vulnerable to fragmentation.

Knowing which species are most vulnerable is critical to understanding the impact of fragmentation. Behavioral patterns, resource needs, reproductive biology, and natural history can be used to identify species that are most vulnerable to fragmentation. Below is a list of characteristics that are typical of species more vulnerable to fragmentation:

- Rare species with restricted distributions
- Rare species with small populations
- Species with large home ranges
- Species that require heterogeneous landscapes
- Species that avoid matrix habitats
- Species with very specialized habitat requirements
- Species with limited dispersal abilities
- Species with low fecundity
- Species with variable population sizes using patchy resources
- Ground nesters vulnerable to medium-sized predators at edges
- Species vulnerable to hunting
- Species that are arboreal (canopy dwellers)
- Co-evolved species (e.g., plants with specific pollinators)

- Invasive species

Invasive species are a present and growing concern for conservation scientists. **Invasive species** are generally non-indigenous species with large, expanding populations that are causing significant (usually detrimental) effects in this new region. While many organisms and species are introduced to new habitats naturally, deliberately, and/or inadvertently, relatively few reach "invasive" status. There are numerous factors that determine the success or failure of a particular species to become established, including the attributes of the invaders and community vulnerability. Successful invasions can inflict profound ecological and economic costs. In response, there are a variety of methods used to prevent and control invasive species, such as eradication and restoration

With or without human help, organisms are transported to new areas where their descendants proliferate, spread, and persist. A wide variety of terrestrial, freshwater, and marine ecosystems have been impacted by non-indigenous species. In many cases, they cause dramatic changes in the ecosystems to which they have been introduced.

Biological invasions are sometimes compared to climate change in the magnitude of their effect on world biota. In a worst-case scenario, continuation of this process at its current rate could result in the creation of homogeneous, simplified ecosystems.

The geographic scope, frequency, and number of species involved in biological invasions have grown enormously during the past two centuries as a direct result of increased human transport and commerce. Not surprisingly, the study of this topic is a rapidly growing scientific area exploring mechanisms behind species establishment in non-native areas, the impact of such introductions on native ecology, theoretical bases of invasion-related phenomena, and the economic and sociopolitical costs inflicted by exotic species. Failure to address these issues may have dire consequences, including disruption of vital ecological processes, decreased production of food and fiber, and epidemics of serious diseases within human populations.

Although movements of populations into new habitats are natural occurrences, the geographic scope of biological invasions, frequency, and the number of species involved have grown enormously in recent centuries. This is a direct consequence of the development of human civilization, particularly advances in human distribution, transportation, and commerce.

Species are intentionally introduced by humans into new habitats for a variety of reasons. Humans carry seeds, plants, and animals with them when colonizing new lands. Plants and animals are exchanged from one region of the world to another as new and more successful varieties are developed. The majority of the world's crops are grown outside of their center of origin (for example, corn is not native to Iowa, nor potatoes native to Ireland.

Game animals are specifically bred and released in native and non-native habitats in order to fortify recreational experiences such as hunting and fishing. Stocking rivers and streams around the world with several different trout species has taken a severe toll on numerous native fish species. The introduction of rabbits to Australia has created major environmental disruption and costs an estimated AUD 600 million ($462 million) per year in lost agricultural production.

Pollinators are often intentionally introduced to aid fruit or vegetable production. For example, the European bumblebee, *Bombus terrestris*, is native to continental Europe but has been commercialized to meet the pollination needs of insect-pollinated crops for a sizeable international market.

Inadvertent introductions have increased dramatically with increased human traffic and commerce. Propagules ranging from gametes, seeds, and spores to groups of full-grown organisms are transported in ships' ballast water and cargo, on machinery and equipment, via air travel and ground transportation in automobiles and trains, and in containers and packing material. Products such as soil, seed, and feed can harbor unintended and potentially invasive contaminants such as pathogenic microorganisms, seeds, and invertebrates.

- Disease

The term **disease** broadly refers to any condition that impairs normal function. Commonly, this term is used to describe infectious diseases caused by the presence of viruses, bacteria, parasites and fungi.

Zoonosis. Virtually all **diseases** that can harm us can harm the great apes since we share so many genetic and physiologic properties; indeed this is one reason why chimpanzees were historically a popular disease model. Human diseases that could attack great apes include germs that are easily transmitted and difficult to control, such as respiratory disease or diarrhea-causing pathogens, and also those that persist long in the environment since this creates a higher chance of transmission. These include the common cold, pneumonia, whooping cough, influenza, hepatitis A and B, chicken and small pox, tuberculosis, bacterial meningitis, diphtheria, measles, rubella, mumps, yellow fever, yaws, polio, encephalomyocarditis and Ebola fever.

There are also numerous vector-borne parasitological diseases common to humans and apes, which can be fatal or have severe consequences for normal behavior and health. These vectors transmit infections from one host to another, i.e., insects, domestic animals, and wild mammals. As well as air and vector borne diseases, human feces are a potential source of human pathogen transmission to wild apes. Some of these viruses are particularly important because of their zoonotic potential (transmission of disease from apes to humans, and/or vice versa).

Great apes and humans are close evolutionary relatives and therefore vulnerable to many of the same diseases. As the numbers of people that come into regular contact with apes through hunting, farming, ecotourism, political conflict, research, and conservation-related activities increases, the likelihood of viruses, parasites, and other pathogens passing between them and great apes rises.

Emerging infectious diseases, such as Ebola and anthrax, are endemic to dense forests and have proven deadly to both humans and great apes. It is difficult to distinguish between diseases that are human introduced from those that occur naturally, given the extent of the human footprint on tropical forest environments. Being far more mobile and in contact with a global spectrum of pathogens, humans are much more likely to introduce illness to small, isolated populations of apes than the other way around.

  - Overexploitation (bush meat hunting, overfishing)
- Sustainable use

Article 2 of the Convention on Biological Diversity (CBD) 1992 defines **sustainable use** as the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

READING:
WCF and FDA, "Wildlife & Anthropogenic threats in Grebo-Sapo Corridor"

- Poaching

Poaching is the illegal hunting, killing or capturing of animals contrary to national and international conservation and wildlife management laws and regulations. Poaching can include any of five factors: time, location, number, method or species. For example, hunting without a license or permit, use of a prohibited weapon or trap, hunting outside of the designated time of day or year, hunting of a prohibited sex or life stage, or hunting in protected areas such as national parks. Wildlife species that may be legally hunted are defined and regulated through special open seasons. In the case of great apes that are protected both nationally and internationally, all hunting and trading is illegal and considered poaching. Apes are poached for food (bushmeat) and for the pet trade, and body parts are used for traditional practices and medicine. A distinction is made between subsistence and commercial poaching. Subsistence poaching is hunting and gathering for the sole purpose of providing for yourself and your family, in other words hunting for survival. Commercial hunting is hunting for profit with the sole purpose of economic and/or material gain.

Among the species available for hunting in Liberia are highly prized species such as zebra duiker, water chevrotain, western bongo and dwarf buffalo. Liberia is the best location in Africa for hunting forest duikers.

<u>Human use</u>
Many species are hunted for meat and other products, including whales and various fish, as discussed above. Less familiar is the widespread trade in bushmeat, which is essentially everything that can be hunted—from mice to chimpanzees and gorillas—and is especially prevalent in West and Central Africa. Yet other species are harvested for body parts, such as tiger bones and rhino horns, which are used in Asian medicines. A wide variety of plants are harvested too, again often for medicinal purposes. Simply put, any species that is used for food, wood, or medicine or as pets or houseplants, that is collected (such as butterflies or invertebrate shells), or that attracts attention for any other reason suffers an increased risk of extinction.'

- Threatened species and habitats
  - The IUCN Red list
- Threat Categories

PRACTICUM: USING IUCN RED LIST

The IUCN Red List Programme evaluates the status of species relative to other species in terms of a species' extinction risk and allows for monitoring. The IUCN Red List is a tool to help assess and monitor the status of biodiversity at the species level (www.redlist.org). The Red List helps provide a qualitative estimate of the risk of extinction.

The IUCN Red List identifies those species most in need of conservation attention if global extinction rates are to be reduced. The listing process utilizes a comprehensive system of threat classification and criteria to place species in one of seven broad categories [see Table below]. For example, the 2004 IUCN Red List contains 15,589 species threatened with extinction. The assessment includes species from a broad range of taxonomic groups including vertebrates, invertebrates, plants, and fungi.

Liberia has a number of threatened and endangered species. For instance, the Nimba toad, an amphibian endemic to Liberia and surrounding countries, is critically endangered. In addition, the western chimpanzee is also listed as a critically endangered species in Liberia.

Human Threats to Wildlife: Great Apes

READINGS

Kuhl et al (2017), "Critically endangered chimpanzee population declines by 80%"

Greengrass (2016) "Commercial hunting in Sapo National Park"

The western chimpanzee is Critically Endangered. The categories indicating a species' status are: Critically Endangered, Endangered and Vulnerable.

The extent of the threat of poaching varies according to species and sub-species, has local, regional and international dimensions, and can change over time. Poaching of a commercial nature is listed as a threat, and in many cases is the most important threat to all sub-species of great ape.

For example, *Pan troglodytes ellioti* is present in Nigeria and Cameroon. Whilst logging is a main threat, commercial poaching is probably the greatest threat, exacerbated by easy access to modern weapons and transport systems, and high financial incentives for supplying bushmeat to an increasing urbanized (and wealthy) population. Poaching of chimpanzees for bushmeat occurs throughout their range. Young chimpanzees captured as a by-product of poaching are sold as pets. There is significant illegal trade in wildlife and wildlife products, and Nigeria and Cameroon have been identified as key source countries for the illegal trade in apes within and out of Africa, and indeed Nigeria was subject to a CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) ban until 2011.

The direct impact of poaching is loss of individuals to the wild population. While trade in live apes for the pet trade is the driving force, studies suggest that the many more individuals die for each chimpanzee that reaches its commercial destination. These figures include the loss of other protective adults and the estimation that of five infants captured only one will survive the journey. For example, adult gorillas have been killed trying to protect their infants. Groups may disintegrate in response to loss of the dominant silverback and this can result in additional fatalities. With poaching, the loss of reproducing females and diminished genetic variation may increase Great Apes' vulnerability to infectious diseases, can lead to local extinction.

The threat of poaching is inextricably interlinked with other threats to wild populations. Whilst apes are probably, in numerical terms, a small part of the immense trade in bushmeat, poaching is the main reason why African apes are killed. The capture of live infants is often opportunistic rather than direct targeting. The commercialization of the trade in bushmeat is linked to increasing urbanization and associated market economies, modern hunting methods and road networks facilitating access to once remote areas. For example, in the Bili-Gangu region of the Democratic Republic of Congo, the expansion of the bushmeat trade and accompanying presence of live chimpanzee 'refugees' is directly linked to artisanal diamond and gold mining industries. The capture of live infants for the pet trade and instances of human-wildlife conflict (when orangutans enter forest gardens or plantations) are the main reasons why orangutans are killed.

Poaching is particularly dangerous for apes. This is a consequence of low population densities across their range and slow reproductive rates, meaning that apes can take a long time to recover from any reduction in population, and puts them at risk of local extinction but also (where the subspecies is represented by only one population) to the extinction of the subspecies.

- Wildlife trade

TRAFFIC International defines **wildlife trade** as any sale or exchange of wild animal and plant resources by people. This can involve live animals and plants or a diverse range of products needed or prized by humans—including skins, medicinal ingredients, tourist curios, timber, fish and other food products.

  - Pollution

Pollution can be difficult to classify and to measure. There are a wide variety of types of pollution and associated impacts. For wildlife and fauna, the result is disruptive, persistent and cumulative impacts on species. Pollutants resist categorization because of their varied forms and effects. Some directly toxify the environment, such as lead or PCBs, while others, such as fertilizer runoff, are non-toxic but harm aquatic systems by causing excessive plant growth. Noise and light pollution threaten species by disrupting their behavior.

Pollutants are also classified by the environment they affect, for example, air, water, and soil pollution. Many pollutants cycle through all these environments at some stage, entering the air and eventually ending up in water or soil.

Classification of pollutants may also derive from where they enter the environment: a "point source" pollutant enters at a discrete location and is non-mobile, such as effluent from a sewage treatment plant, whereas a "non-point" source pollutant enters from many locations or is mobile, such as surface runoff into the coastal zone from cars (oil) or lawns (fertilizers and pesticides).

Pollutants can be classified as Toxic or Non-toxic contaminants:

- Toxic - Lethal or interfering with natural functioning (immune, reproductive, etc.)
- Non-toxic – harms ecological systems

Among the most insidious pollutants are those which cause climate change. These are composed of common elements which previously existed in natural amounts in ecosystems. Flows of nitrogen and phosphorous in biological ecosystems, however, have increased drastically since 1960, and the concentration of carbon has increased. These three elements, along with oxygen, form compounds that are responsible for the increased greenhouse effect. Human actions over the last century have created an abundance and imbalance of these; Synthetic Nitrogen was first manufactured in 1913. Since 1750, the atmospheric concentration of carbon dioxide has increased by about 32% (from about 280 to 376 parts per million in 2003), primarily due to the combustion of fossil fuels and land use changes.

  - Climate Change

Evidence from the fossil record and from recently observed trends demonstrate that changes in climate can have a profound influence on the myriad of species that comprise Earth's biodiversity. Predicted climate change over the coming century is therefore likely to have a significant influence on biodiversity. Natural systems comprise a complex web of interactions and feedbacks among species. Individual species and their interactions, whether mutualistic, competitive, predatory, symbiotic, or parasitic, comprise communities. Climate change impacts on a single species could therefore have significant knock-on impacts on many other species, resulting in changes to the community as a whole.

Climate change: the physical science basis

In its Fifth Assessment Report in 2014, the Intergovernmental Panel on Climate Change (IPCC) described increased confidence that human activities are influencing global climate, with widespread impacts on both human and natural systems (IPCC 2014). The following list summarizes some of the main conclusions of the IPCC report.

- Recent anthropogenic emissions of greenhouse gases are the highest in history. Global atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unseen in at least the last 800,000 years.
- Climate system warming is indisputable, with each of the last three decades being successively warmer than any other decade since 1850. It is *extremely likely* that these anthropogenic greenhouse gases, combined with other anthropogenic forces, are the leading cause of warming since the mid 20th century.
- Observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, rising global mean sea level, regional changes in precipitation patterns, and variations in extreme weather events (including droughts, heat waves, and the intensity of tropical cyclones) provide unequivocal evidence that the climate system is changing. Some of these changes, such as increases in temperature extremes and heavy precipitation events, have been linked to human influence.
- For the next two decades, global average warming of between 0.3°C and 0.7°C is *likely*, as projected by a range of emissions scenarios. This rise in surface temperature is *very likely* to be accompanied by increased frequency and intensity of heat waves and extreme precipitation events, increased ocean warming, and increased sea level rise.
- Continued greenhouse gas emissions at or above current rates would cause further warming and induce many widespread, irreversible changes in the global climate system by the end of the 21st century.

▪ Predicted and Measured Responses of Ecosystems to Climate Change

Anthropogenic climate change is now in full swing, our global average temperature already having increased by 1°C from preindustrial levels. Many studies have documented individual impacts of the changing climate that are particular to species or regions, but individual impacts are accumulating and being amplified more broadly. Predicting how species will respond to climate change is a critical part of efforts to prevent widespread climate-driven extinction, or to predict its consequences for ecosystem. Understanding how interactions among species in ecological communities will change as a consequence of climate change is a critical part of predicting the consequences for ecosystem function.

▪ What types of responses do we expect to see by species?

Climate influences ecological phenomena by impacting the distribution and activity of organisms, the development of soils, the availability of surface and sub-surface water, and the spatial and temporal dynamics of virtually all ecosystem processes. Climate also acts on connections among ecosystems, by altering rates and patterns of transport of materials through the movement of air masses, surface waters, migratory animals, and vegetative and microbial propagules. In addition, climate drives the spread of disturbances such as fire.

Broader-scale responses to climate change include changes in the phenology, abundance, and distribution of species. Temperate plants are budding and flowering earlier in spring and later in autumn. Comparable adjustments have been observed in marine and freshwater fish spawning events and in the timing of seasonal migrations of animals worldwide. Changes in the abundance and age structure of populations have also been observed, with widespread evidence of range expansion in warm-adapted species and range contraction in cold-adapted species. As a by-product of species redistributions, novel community interactions have emerged. Tropical and boreal species are increasingly incorporated into temperate and polar communities, respectively, and when possible, lowland species are increasingly assimilating into mountain communities. Multiplicative impacts from gene to community levels scale up to produce ecological regime shifts, in which one ecosystem state shifts to an alternative state.

- Predictions of species loss with climate change

Current predictions on species responses to climate change strongly rely on projecting altered environmental conditions on species distributions. However, it is increasingly acknowledged that climate change also influences species interactions.

The most proximate effects of climate change are in the phenology of species. For example, spring temperature strongly determines germination and bud burst of plants, as well as foraging and reproductive activities of animals.

Climate change can alter the setting of range limits, leading to range expansion, or range contraction. Range shifts may result in decoupling of trophic interactions by a number of different causes, including differences in dispersal rate and the inability of predators and preys to interact in the new range. Both these and other factors may influence selection pressures and evolution of species.

- Liberia and Climate Change
- **Liberia's vulnerability to climate change**

Liberia is susceptible to climate change, due its geographic location and climate properties. While Liberia has no power plants to produce excess greenhouse gases, the following activities here contribute to climate change: shifting cultivation, unsustainable logging practices, unregulated coastal mining, high levels of biomass consumption (charcoal and firewood), and non-regulation burning of garbage (including plastics). Climate change in Liberia will cause **higher temperatures**, **decreased river flows due to high evaporation**, more extreme weather events such as **heavier rains**, and **rising sea levels**. The effects of increasing climatic variability and climatic change threaten key economic sectors in Liberia, namely agriculture, fisheries, forestry, energy, health, meteorology/hydrology. Agricultural productivity and fisheries are vulnerable to a changing climate, and saltwater and freshwater fisheries are likely to suffer as sea temperatures increase and coastal ecosystems (mangroves and wetlands) are damaged.

- **Support to vulnerable communities (adaptation)**

<u>Shoreline erosion</u>

Coastal zones are home to the majority of Liberia's population, infrastructure, and economic activity and are at risk from flooding and erosion associated with sea level rise. Sea level rise is projected to increase along Liberia's coast and cause more frequent flooding in coastal cities, especially Monrovia.

A 1-meter rise in sea level would put an estimated 230,000 Liberians at risk and cause a loss of 2,150 square kilometers of land and infrastructure, which is valued at US$250 million.

<u>Diseases</u>

An increase in flooding due to sea level rise will also put Liberians at **greater risk to epidemics** of malaria, cholera, and diarrheal diseases, and increases in the incidences of Lassa fever, schistosomiasis, lymphatic filariasis, yellow fever, hepatitis A, and intestinal worms. Malaria poses the most significant threat to public health as it has the highest mortality rate.

- **National REDD+ strategy and pilot sites**

Liberia is a signatory to the United Nations' Paris Climate Change Agreement. The 2017 National Policy and Response Strategy on Climate Change guides the country's efforts to mitigate the risks of climate change and reduce vulnerability.

REDD+

'*Reducing Emissions due to Deforestation and forest Degradation* in developing countries and associated activities that protect against climate change' is an initiative that designates a dollar value for territories with standing forests according to the amount that would be released if the forests were destroyed. This gives developed countries a way to meet emissions standards by paying to keep forests in the developing world standing. The money is then allocated to incentivize forest community-members, who would otherwise need to cut down the forests for income.

The Forest Development Authority (FDA) and the Environmental Protection Agency (EPA) are the key government agencies involved in the REDD+ program.
Objectives of REDD+ in Liberia

- Reducing emissions from deforestation and forest degradation
- Conservation of forest carbon stocks
- Sustainable management of forests
- Enhancement of forest carbon stocks

- **Relationships between protected areas and climate change adaptation**

If total forest area increases, there is potential for increase in carbon uptake, thus forested protected areas can contribute to slowing and reversal of climate change. Changes in climate appear to have increased global net primary productivity in recent decades, raising the effectiveness of forested carbon sequestration potential. The rate of carbon sequestration normally decreases with time.