Wildlife Conservation and Management

Kason Hurst

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Edited by
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Preface

Conserving wildlife is the need of the hour. Due to the burgeoning human population, the ecosystems of plants and animals are getting degraded and are creating a huge wildlife crisis. To stop the exploitation of wildlife environments for human benefit, wildlife management is crucial. This book aims to make the subjects of wildlife conservation and wildlife management easier. The topics included in it provide students with the basic theories related to the field. Also explained are the various allied branches that are related to this field. Coherent flow of topics, student-friendly language and extensive use of examples make this textbook an invaluable source of knowledge.

A short introduction to every chapter is written below to provide an overview of the content of the book:

Chapter 1 - Wildlife is referred to species that have historically not been domesticated. Wildlife includes animals, plants and other organisms that grow in the wild. Humans tend to separate their species from wildlife in a number of ways. This chapter helps the reader in understanding the difference between civilization and wildlife; **Chapter 2 -** Wildlife conservation is the practice of protecting wildlife. The aim of conserving wildlife is to make sure that it will be around for the future generations to witness. It has become an increasingly important practice in the present time. The text on wildlife conservation offers an insightful focus, keeping in mind the complex subject matter; **Chapter 3 -** Wildlife conservation faces a number of concerns. Some of these are Holocene extinction, poaching, human-wildlife conflict, disturbance and habitat destruction. The capturing of wild animals is known as poaching whereas disturbance is the change in environmental conditions that forces a change in the ecosystem. The topics discussed in the section are of great importance to broaden the existing knowledge on concerns and challenges of wildlife conservation; **Chapter 4 -** The process of recreating a breed of species that has become extinct is known as de-extinction. Captive breeding is the process of breeding animals in an environment that is monitored by humans, such as wildlife and zoos. This chapter has been carefully written to provide an easy understanding of the diverse approaches to wildlife conservation; **Chapter 5 -** A habitat is an environment that is inhabited by animals, plants and species. Habitat conservation is the conservation and protection of habitat areas. Habitat fragmentation, habitat cascade and habitat conservation are some of the topics that have been elucidated in the following text; **Chapter 6 -** Species that have been classified by the international union for conservation of nature for having the highest probability of becoming extinct is known as endangered species. The various endangered species discussed in this section are passenger pigeons, Asiatic lions and snow leopards. This chapter is an overview of the subject matter incorporating all the major aspects of endangered species;

Chapter 7 - Humans have caused immense loss to the natural habitat of wild plants and animals. Species reintroduction is the release of animals and organisms from captivity into the wild. It is usually done for animals that are under threat and are very close to becoming extinct. Specific species reintroduction includes topics such as Siberian Tiger Re-population Project, Cheetah reintroduction in India and the Arabian Oryx reintroduction. The aspects elaborated in this section are of vital importance, and provide a better understanding of species reintroduction.

I extend my sincere thanks to the publisher for considering me worthy of this task. Finally, I thank my family for being a source of support and help.

Editor

1

Introduction to Wildlife

Wildlife is referred to species that have historically not been domesticated. Wildlife includes animals, plants and other organisms that grow in the wild. Humans tend to separate their species from wildlife in a number of ways. This chapter helps the reader in understanding the difference between civilization and wildlife.

Wildlife traditionally refers to undomesticated animal species, but has come to include all plants, fungi, and other organisms that grow or live wild in an area without being introduced by humans.

Panthera tigris

Wildlife can be found in all ecosystems. Deserts, forests, rain forests, plains, grasslands, and other areas including the most developed urban sites, all have distinct forms of wildlife. While the term in popular culture usually refers to animals that are untouched by human factors, most scientists agree that much wildlife is affected by human activities.

Humans have historically tended to separate civilization from wildlife in a number of ways including the legal, social, and moral sense. Some animals, however, have adapted to suburban environments. This includes such animals as domesticated cats, dogs, mice, and gerbils. Some religions declare certain animals to be sacred, and in modern times concern for the natural environment has provoked activists to protest against the exploitation of wildlife for human benefit or entertainment.

The global wildlife population has decreased by 52 percent between 1970 and 2014, according to a report by the World Wildlife Fund.

Food, Pets, and Traditional Medicines

Anthropologists believe that the Stone Age people and hunter-gatherers relied on wildlife, both plants and animals, for their food. In fact, some species may have been hunted to extinction by early human hunters. Today, hunting, fishing, and gathering wildlife is still a significant food source in some parts of the world. In other areas, hunting and non-commercial fishing are mainly seen as a sport or recreation, with the edible meat as mostly a side benefit of it. Meat sourced from wildlife that is not traditionally regarded as game is known as bush meat. The increasing demand for wildlife as a source of traditional food in East Asia is decimating populations of sharks, primates, pangolins and other animals, which they believe have aphrodisiac properties.

A mesh bag full of live frogs waiting for a buyer at Chiang Mai's Thanin market. Frog meat in Thailand is mostly used in stir-fries and Thai curries.

In November 2008, almost 900 plucked and "oven-ready" owls and other protected wildlife species were confiscated by the Department of Wildlife and National Parks in Malaysia, according to TRAFFIC. The animals were believed to be bound for China, to be sold in wild meat restaurants. Most are listed in CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) which prohibits or restricts such trade.

> " Malaysia is home to a vast array of amazing wildlife. However, illegal hunting and trade poses a threat to Malaysia's natural diversity. "
>
> —*Chris S. Shepherd*

A November 2008 report from biologist and author Sally Kneidel, PhD, documented numerous wildlife species for sale in informal markets along the Amazon River, including wild-caught marmosets sold for as little as $1.60 (5 Peruvian soles). Many Amazon species, including peccaries, agoutis, turtles, turtle eggs, anacondas, armadillos, etc., are sold primarily as food. Others in these informal markets, such as monkeys and parrots, are destined for the pet trade, often smuggled into the United States. Still other

Amazon species are popular ingredients in traditional medicines sold in local markets. The medicinal value of animal parts is based largely on superstition.

Religion

Many animal species have spiritual significance in different cultures around the world, and they and their products may be used as sacred objects in religious rituals. For example, eagles, hawks and their feathers have great cultural and spiritual value to Native Americans as religious objects. In Hinduism the cow is regarded sacred.

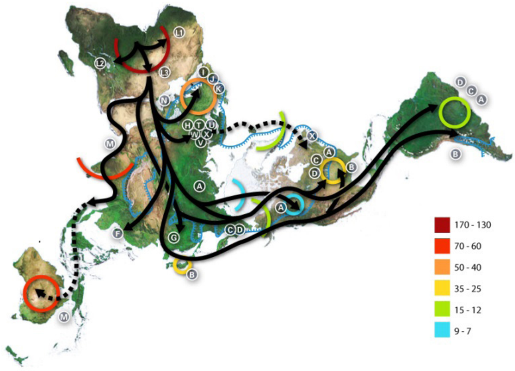
Muslims conduct sacrifices on Eid-ul-Adha to commemorate the sacrificial spirit of Ibrahim [Abraham] in love of God. Camels, sheep, goats, and cows may be offered as sacrifice during the three days of Eid.

Tourism

Many nations have established their tourism sector around their natural wildlife. South Africa has, for example, many opportunities for tourists to see the country's wildlife in its national parks, such as the Kruger Park. In South India the Periar Wildlife Sanctuary, Bandipur National Park and Mudamalai Wildlife Sanctuary are situated around and in forests. India is home to many national parks and wildlife sanctuaries showing the diversity of its wildlife, much of its unique fauna, and excels in the range. There are 89 national parks, 13 bio reserves and more than 400 wildlife sanctuaries across India which are the best places to go to see tigers, lions, elephants, rhinoceros, birds, and other wildlife which reflect the importance that the country places on nature and wildlife conservation.

Destruction

This subsection focuses on anthropogenic forms of wildlife destruction.



Map of early human migrations, according to mitochondrial population genetics. Numbers are millennia before the present.

Exploitation of wild populations has been a characteristic of modern man since our exodus from Africa 130,000 – 70,000 years ago. The rate of extinctions of entire species of plants and animals across the planet has been so high in the last few hundred years it is widely believed that we are in the sixth great extinction event on this planet; the Holocene Mass Extinction.

Destruction of wildlife does not always lead to an extinction of the species in question, however, the dramatic loss of entire species across Earth dominates any review of wildlife destruction as extinction is the level of damage to a wild population from which there is no return.

The four most general reasons that lead to destruction of wildlife include overkill, habitat destruction and fragmentation, impact of introduced species and chains of extinction.

Overkill

Wildlife is an invaluable treasure but it is being exploited due to illegal trade of many of its species.Overkill happens whenever hunting occurs at rates greater than the reproductive capacity of the population is being exploited. The effects of this are often noticed much more dramatically in slow growing populations such as many larger species of fish. Initially when a portion of a wild population is hunted, an increased availability of resources (food, etc.) is experienced increasing growth and reproduction as density dependent inhibition is lowered. Hunting, fishing and so on, has lowered the competition between members of a population. However, if this hunting continues at rate greater than the rate at which new members of the population can reach breeding age and produce more young, the population will begin to decrease in numbers.

Populations that are confined to islands, whether literal islands or just areas of habitat that are effectively an "island" for the species concerned, have also been observed to be at greater risk of dramatic population declines following unsustainable hunting.

Habitat Destruction and Fragmentation

Deforestation and increased road-building in the Amazon Rainforest are a significant concern because of increased human encroachment upon wild areas, increased resource extraction and further threats to biodiversity.

The habitat of any given species is considered its preferred area or territory. Many processes associated with human habitation of an area cause loss of this area and decrease the carrying capacity of the land for that species. In many cases these changes in land use cause a patchy break-up of the wild landscape. Agricultural land frequently displays this type of extremely fragmented, or relictual, habitat. Farms sprawl across the landscape with patches of uncleared woodland or forest dotted in-between occasional paddocks.

Examples of habitat destruction include grazing of bushland by farmed animals, changes to natural fire regimes, forest clearing for timber production and wetland draining for city expansion.

Impact of Introduced Species

Mice, cats, rabbits, dandelions and poison ivy are all examples of species that have become invasive threats to wild species in various parts of the world. Frequently species that are uncommon in their home range become out-of-control invasions in distant but similar climates. The reasons for this have not always been clear and Charles Darwin felt it was unlikely that exotic species would ever be able to grow abundantly in a place in which they had not evolved. The reality is that the vast majority of species exposed to a new habitat do not reproduce successfully. Occasionally, however, some populations do take hold and after a period of acclimation can increase in numbers significantly, having destructive effects on many elements of the native environment of which they have become part.

Chains of Extinction

This final group is one of secondary effects. All wild populations of living things have many complex intertwining links with other living things around them. Large herbivorous animals such as the hippopotamus have populations of insectivorous birds that feed off the many parasitic insects that grow on the hippo. Should the hippo die out, so too will these groups of birds, leading to further destruction as other species dependent on the birds are affected. Also referred to as a domino effect, this series of chain reactions is by far the most destructive process that can occur in any ecological community.

Another example is the black drongos and the cattle egrets found in India. These birds feed on insects on the back of cattle, which helps to keep them disease-free. Destroying the nesting habitats of these birds would cause a decrease in the cattle population because of the spread of insect-borne diseases.

Media

Wildlife has long been a common subject for educational television shows. National Geographic specials appeared on CBS beginning in 1965, later moving to ABC and then

PBS. In 1963, NBC debuted *Wild Kingdom,* a popular program featuring zoologist Marlin Perkins as host. The BBC natural history unit in the UK was a similar pioneer, the first wildlife series LOOK presented by Sir Peter Scott, was a studio-based show, with filmed inserts. It was in this series that David Attenborough first made his appearance which led to the series Zoo Quest during which he and cameraman Charles Lagus went to many exotic places looking for and filming elusive wildlife—notably the Komodo dragon in Indonesia and lemurs in Madagascar. Since 1984, the Discovery Channel and its spin off Animal Planet in the US have dominated the market for shows about wildlife on cable television, while on PBS the NATURE strand made by WNET-13 in New York and NOVA by WGBH in Boston are notable. Wildlife television is now a multimillion-dollar industry with specialist documentary film-mak-ers in many countries including UK, US, New Zealand NHNZ, Australia, Austria, Ger-many, Japan, and Canada. There are many magazines which cover wildlife including National Wildlife Magazine, Birds & Blooms, Birding (magazine), and Ranger Rick (for children).

The Douglas Squirrel (*Tamiasciurus douglasii*) is an example of wildlife.

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2

Wildlife Conservation and Management: An Integrated Study

Wildlife conservation is the practice of protecting wildlife. The aim of conserving wildlife is to make sure that it will be around for the future generations to witness. It has become an increasingly important practice in the present time. The text on wildlife conservation offers an insightful focus, keeping in mind the complex subject matter.

Wildlife Conservation

Wildlife Conservation is the practice of protecting wild plant and animal species and their habitats. The goal of wildlife conservation is to ensure that nature will be around for future generations to enjoy and also to recognize the importance of wildlife and wilderness for humans and other species alike. Many nations have government agencies and NGO's dedicated to wildlife conservation, which help to implement policies designed to protect wildlife. Numerous independent non-profit organizations also promote various wildlife conservation causes.

The Siberian tiger is a subspecies of tiger that is endangered; three subspecies of tiger are already extinct.

According to the National Wildlife Federation, wildlife in the United States gets a majority of their funding through appropriations from the federal budget, annual federal and state grants, and financial efforts from programs such as the Conservation Reserve Program, Wetlands Reserve Program and Wildlife Habitat Incentives Program.

Furthermore, a substantial amount of funding comes from the state through the sale of hunting/fishing licenses, game tags, stamps, and excise taxes from the purchase of hunting equipment and ammunition, which collects around $200 million annually.

Wildlife conservation has become an increasingly important practice due to the negative effects of human activity on wildlife. An endangered species is defined as a population of a living species that is in the danger of becoming extinct because of several reasons.Some of The reasons can be, that 1. the species have a very low population, or 2. they are threatened by the varying environmental or prepositional parameters.

Major Dangers to Wildlife

Fewer natural wildlife habitat areas remain each year. Moreover, the habitat that remains has often been degraded to bear little resemblance to the wild areas which existed in the past.Habitat loss—due to destruction, fragmentation and degradation of habitat—is the primary threat to the survival of wildlife in the United States. When an ecosystem has an ecosystem are some of the ways habitats can become so degraded that they no longer support native wildlife.

- Climate change: Global warming is making hot days hotter, rainfall and flooding heavier, hurricanes stronger and droughts more severe. This intensification of weather and climate extremes will be the most visible impact of global warming in our everyday lives. It is also causing dangerous changes to the landscape of our world, adding stress to wildlife species and their habitat. Since many types of plants and animals have specific habitat requirements, climate change could cause disastrous loss of wildlife species. A slight drop or rise in average rainfall will translate into large seasonal changes. Hibernating mammals, reptiles, amphibians and insects are harmed and disturbed. Plants and wildlife are sensitive to moisture change so, they will be harmed by any change in moisture level. Natural phenomena like floods, earthquakes, volcanoes, lightning, forest fires.
    - Unregulated Hunting and poaching: Unregulated hunting and poaching causes a major threat to wildlife. Along with this, mismanagement of forest department and forest guards triggers this problem.
    - Pollution: Pollutants released into the environment are ingested by a wide variety of organisms. Pesticides and toxic chemical being widely used, making the environment toxic to certain plants, insects, and rodents.
    - Perhaps the largest threat is the extreme growing indifference of the public to wildlife, conservation and environmental issues in general. Over-exploitation of resources, i.e., exploitation of wild populations for food has resulted in population crashes (over-fishing and over-grazing for example).

- Over exploitation is the over use of wildlife and plant species by people for food, clothing, pets, medicine, sport and many other purposes. People have always depended on wildlife and plants for food, clothing, medicine, shelter and many other needs. But today we are taking more than the natural world can supply. The danger is that if we take too many individuals of a species from their natural environment, the species may no longer be able to survive. The loss of one species can affect many other species in an ecosystem. The hunting, trapping, collecting and fishing of wildlife at unsustainable levels is not something new. The passenger pigeon was hunted to extinction, early in the last century, and over-hunting nearly caused the extinction of the American bison and several species of whales.

- Deforestation: Humans are continually expanding and developing, leading to an invasion of wildlife habitats. As humans continue to grow they clear forested land to crewe more space. This stresses wildlife populations as there are fewer homes and food sources to survive off of.

Population: The increasing population of human beings is the most major threat to wildlife. More people on the globe means more consumption of food,water and fuel . Therefore,more waste is generated. Every major threat to wildlife as seen above, is directly related to increasing population of human beings. If the population is altered so is the amount of risk to wildlife. The less is the population, less is the disturbance to wildlife.

Today, the [Endangered Species Act] protects some U.S. species that were in danger from over exploitation, and the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) works to prevent the global trade of wildlife. But there are many species that are not protected from being illegally traded or over-harvested.

Wildlife Conservation as a Government Involvement

In 1972, the Government of India enacted a law called the Wild Life (Protection) Act.The World Conservation Strategy was developed in 1980 by the “International Union for Conservation of Nature and Natural Resources” (IUCN) with advice, cooperation and financial assistance of the United Nations Environment Programme (UNEP) and the World Wildlife Fund and in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Educational, Scientific and Cultural Organization (Unesco)” The strategy aims to “provide an intellectual framework and practical guidance for conservation actions.” This thorough guidebook covers everything from the intended “users” of the strategy to its very priorities. It even includes a map section containing areas that have large seafood consumption and are therefore endangered by over fishing. The main sections are as follows:

The marking off of a sea turtle nest. Anna Maria, FL. 2012.

- The objectives of conservation and requirements for their achievement:

1. Maintenance of essential ecological processes and life-support systems.
2. Preservation of genetic diversity that is flora and fauna.
3. Sustainable utilization of species and ecosystems.

- Priorities for national action:

1. A framework for national and sub-national conservation strategies.
2. Policy making and the integration of conservation and development.
3. Environmental planning and rational use allocation.

- Priorities for international action:

1. International action: law and assistance.
2. Tropical forests and dry lands.
3. A global programme for the protection of genetic resource areas.

Map sections:

1. Tropical forests
2. Deserts and areas subject to desertification.

Non-government Involvement

As major development agencies became discouraged with the public sector of environmental conservation in the late 1980s, these agencies began to lean their support towards the “private sector” or non-government organizations (NGOs). In a World

Bank Discussion Paper it is made apparent that "the explosive emergence of nongovernmental organizations" was widely known to government policy makers. Seeing this rise in NGO support, the U.S. Congress made amendments to the Foreign Assistance Act in 1979 and 1986 "earmarking U.S. Agency for International Development (USAID) funds for biodiversity". From 1990 moving through recent years environmental conservation in the NGO sector has become increasingly more focused on the political and economic impact of USAID given towards the "Environment and Natural Resources". After the terror attacks on the World Trade Centers on September 11, 2001 and the start of former President Bush's War on Terror, maintaining and improving the quality of the environment and natural resources became a "priority" to "prevent international tensions" according to the Legislation on Foreign Relations Through 2002 and section 117 of the 1961 Foreign Assistance Act. Furthermore, in 2002 U.S. Congress modified the section on endangered species of the previously amended Foreign Assistance Act.

Active non-government Organizations

Many NGOs exist to actively promote, or be involved with wildlife conservation:

- The Nature Conservancy is a US charitable environmental organization that works to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.
- World Wide Fund for Nature (WWF) is an international non-governmental organization working on issues regarding the conservation, research and restoration of the environment, formerly named the World Wildlife Fund, which remains its official name in Canada and the United States. It is the world's largest independent conservation organization with over 5 million supporters worldwide, working in more than 90 countries, supporting around 1300 conservation and environmental projects around the world. It is a charity, with approximately 60% of its funding coming from voluntary donations by private individuals. 45% of the fund's income comes from the Netherlands, the United Kingdom and the United States.
- WildTeam
- Wildlife Conservation Society
- Audubon Society
- Traffic (conservation programme)
- Born Free Foundation
- WildEarth Guardians

Wildlife Management

Wildlife management attempts to balance the needs of wildlife with the needs of people using the best available science. Wildlife management can include game keeping, wildlife conservation and pest control. Wildlife management draws on disciplines such as mathematics, chemistry, biology, ecology, climatology and geography to gain the best results.

Wildlife conservation aims to halt the loss in the Earth's biodiversity by taking into consideration ecological principles such as carrying capacity, disturbance and succession and environmental conditions such as physical geography, pedology and hydrology with the aim of balancing the needs of wildlife with the needs of people. Most wildlife biologists are concerned with the preservation and improvement of habitats although rewilding is increasingly being used. Techniques can include reforestation, pest control, nitrification and denitrification, irrigation, coppicing and hedge laying.

Game keeping is the management or control of wildlife for the well being of game and may include killing other animals which share the same niche or predators to maintain a high population of the more profitable species, such as pheasants introduced into woodland. In his 1933 book *Game Management*, Aldo Leopold, one of the pioneers of wildlife management as a science, defined it as "the art of making land produce sustained annual crops of wild game for recreational use".

Pest control is the control of real or perceived pests and can be for the benefit of wildlife, farmers, game keepers or safety reasons. In the United States, wildlife management practices are often implemented by a governmental agency to uphold a law, such as the Endangered Speci

In the United Kingdom, wildlife management undertaken by several organizations including government bodies such as the Forestry Commission, Charities such as the RSPB and The Wildlife Trusts and privately hired gamekeepers and contractors. Legislation has also been passed to protect wildlife such as the Wildlife and Countryside Act 1981. The UK government also give farmers subsidies through the Countryside Stewardship Scheme to improve the conservation value of their farms.

History

Game Laws

The history of wildlife management begins with the game laws, which regulated the right to kill certain kinds of fish and wild animal (game). In Britain game laws developed out of the forest laws, which in the time of the Norman kings were very oppressive. Under William the Conqueror, it was as great a crime to kill one of the king's deer as to kill one of his subjects. A certain rank and standing, or the possession of a certain amount of property, were for a long time qualifications indispensably necessary to confer upon any one the right of pursuing and killing game.

The Game Act of 1831 protected game birds by establishing close seasons when they could not be legally taken. The act made it lawful to take game only with the provision of a game licence and provided for the appointment of gamekeepers around the country. The purposes of the law was to balance the needs for preservation and harvest and to manage both environment and populations of fish and game.

The Game Act 1831 protects game birds in England and Wales

Early game laws were also enacted in the US; - in 1839 Rhode Island closed the hunting season for white-tailed deer from May to November. Other regulations during this time focused primarily on restricting hunting. At this time, lawmakers did not consider population sizes or the need for preservation or restoration of wildlife habitats.

Emergence of Wildlife Conservation

The late 19th century saw the passage of the first pieces of wildlife conservation legislation and the establishment of the first nature conservation societies. The Sea Birds Preservation Act of 1869 was passed in Britain as the first nature protection law in the world after extensive lobbying from the Association for the Protection of Seabirds.

The Royal Society for the Protection of Birds was founded as the Plumage League in 1889 by Emily Williamson at her house in Manchester as a protest group campaigning against the use of great crested grebe and kittiwake skins and feathers in fur clothing. The group gained popularity and eventually amalgamated with the Fur and Feather League in Croydon to form the RSPB. The Society attracted growing support from the suburban middle-classes as well as support from many other influential figures, such as the ornithologist Professor Alfred Newton.

The National Trust formed in 1895 with the manifesto to "...promote the permanent preservation, for the benefit of the nation, of lands, ...to preserve (so far practicable) their natural aspect." On 1 May 1899, the Trust purchased two acres of Wicken Fen with a donation from the amateur naturalist Charles Rothschild, establishing the first nature reserve in Britain. Rothschild was a pioneer of wildlife conservation in Britain, and went on to establish many other nature reserves, such as one at Woodwalton Fen, near Huntingdon, in 1910. During his lifetime he built and managed his estate at Ashton Wold in Northamptonshire to maximise its suitability for wildlife, especially butterflies. Concerned about the loss of wildlife habitats, in 1912 he set up the Society for the Promotion of Nature Reserves, the forerunner of The Wildlife Trusts partnership.

During the society's early years, membership tended to be made up of specialist naturalists and its growth was comparatively slow. The first independent Trust was formed in Norfolk in 1926 as the Norfolk Naturalists Trust, followed in 1938 by the Pembrokeshire Bird Protection Society which after several subsequent changes of name is now the Wildlife Trust of South and West Wales and it was not until the 1940s and 1950s that more Naturalists' Trusts were formed in Yorkshire, Lincolnshire, Leicestershire and Cambridgeshire. These early Trusts tended to focus on purchasing land to establish nature reserves in the geographical areas they served.

Wildlife Management in the US

The profession of wildlife management was established in the United States in the 1920s and '30s by Aldo Leopold and others who sought to transcend the purely restrictive policies of the previous generation of conservationists, such as anti-hunting activist William T. Hornaday. Leopold and his close associate Herbert Stoddard, who had both been trained in scientific forestry, argued that modern science and technology could be used to restore and improve wildlife habitat and thus produce abundant "crops" of ducks, deer, and other valued wild animals.

The institutional foundations of the profession of wildlife management were established in the 1930s, when Leopold was granted the first university professorship in wildlife management (1933, University of Wisconsin, Madison), when Leopold's textbook 'Game Management' was published (1933), when The Wildlife Society was founded, when the Journal of Wildlife Management began publishing, and when the first Cooperative Wildlife Research Units were established. Conservationists planned many projects throughout the 1940s. Some of which included the harvesting of female mammals such as deer to decrease rising populations. Others included waterfowl and wetland research. The Fish and Wildlife Management Act was put in place to urge farmers to plant food for wildlife and to provide cover for them.

In 1937, the Federal Aid in Wildlife Restoration Act (also known as the Pittman-Robertson Act) was passed in the U.S.. This law was an important advancement in the field of wildlife management. It placed a 10% tax on sales of guns and ammunition. The funds generated were then distributed to the states for use in wildlife management activities and research. This law is still in effect today.

Wildlife management grew after World War II with the help of the GI Bill and a postwar boom in recreational hunting. An important step in wildlife management in the United States national parks occurred after several years of public controversy regarding the forced reduction of the elk population in Yellowstone National Park. In 1963, United States Secretary of the Interior Stewart Udall appointed an advisory board to collect scientific data to inform future wildlife management. In a paper known as the Leopold Report, the committee observed that culling programs at other national parks had been ineffective, and recommended active management of Yellowstone's elk population.

Elk overpopulation in Yellowstone is thought by many wildlife biologists, such as Douglas Smith, to have been primarily caused by the extirpation of wolves from the park and surrounding environs. After wolves were removed, elk herds increased in population, reaching new highs during the mid-1930s. The increased number of elk apparently resulted in overgrazing in parts of Yellowstone. Park officials decided that the elk herd should be managed. For approximately thirty years, the park elk herds were culled: Each year some were captured and shipped to other locations, a certain number were killed by park rangers, and hunters were allowed to take more elk that migrated outside the park. By the late 1960s the herd populations dropped to historic lows (less than 4,000 for the Northern Range herd). This caused outrage among both conservationists and hunters. The park service stopped culling elk in 1968. The elk population then rebounded. Twenty years later there were 19,000 elk in the Northern Range herd, a historic high.

Since the tumultuous 1970s, when animal rights activists and environmentalists began to challenge some aspects of wildlife management, the profession has been overshadowed by the rise of conservation biology. Although wildlife managers remain central to the implementation of the Endangered Species Act and other wildlife conservation policies, conservation biologists have shifted the focus of conservation away from wildlife management's concern with the protection and restoration of single species and toward the maintenance of ecosystems and biodiversity.

Types of Wildlife Management

There are n a population, either changing its numbers by direct means or influencing numbers by the indirect means of altering food supply, habitat, density of predators, or prevalence of disease. This is appropriate when a population is to be harvested, or when it slides to an unacceptably low density or increases to an unacceptably high level. Such densities are inevitably the subjective view of the land owner, and may be disputed by animal welfare interests.

- Custodial management is preventive or protective. The aim is to minimize external influences on the population and its habitat. It is appropriate in a national park where one of the stated goals is to protect ecological processes. It is also appropriate for conservation of a threatened species where the threat is of external origin rather than being intrinsic to the system. Feeding of animals by visitors is generally discouraged.

Opposition

The control of wildlife through killing and hunting has been criticized by animal rights and animal welfare activists. Critics object to the real or perceived cruelty involved in some forms of wildlife management.

Environmentalists have also opposed hunting where they believe it is unnecessary or will negatively affect biodiversity. Critics of game keeping note that habitat manipulation and predator control are often used to maintain artificially inflated populations of valuable game animals (including introduced exotics) without regard to the ecological integrity of the habitat.

Game keepers in the UK claim it to be necessary for wildlife conservation as the amount of countryside they look after exceeds by a factor of nine the amount in nature reserves and national parks.

Management of Hunting Seasons

Wildlife management studies, research and lobbying by interest groups help designate times of the year when certain wildlife species can be legally hunted, allowing for surplus animals to be removed. In the United States, hunting season and bag limits are determined by guidelines set by the United States Fish and Wildlife Servicefor migratory game such as waterfowl and other migratory gamebirds. The hunting season and bag limits for state regulated game species such as deer are usually determined by State game Commissions, which are made up of representatives from various interest groups, wildlife biologists, and researchers.

Open and closed season on deer in the UK is legislated for in the Deer Act 1991 and the Deer Act (Scotland) 1996

Open Season

Open season is when wildlife is allowed to be hunted by law and is usually not during the breeding season. Hunters may be restricted by sex, age or class of animal, for instance there may be an open season for any male deer with 4 points or better on at least one side.

Limited Entry

Where the number of animals taken is to be tightly controlled, managers may have a type of lottery system called limited. Many apply, few are chosen. These hunts may still have age, sex or class restrictions.

Closed Season

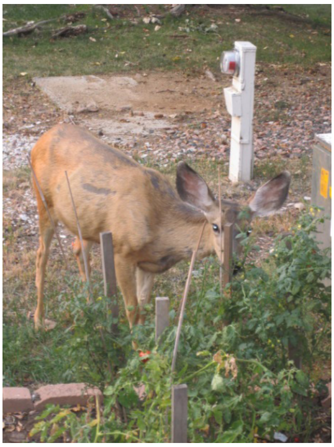
Closed season is when wildlife is protected from hunting and is usually during its breeding season. Closed season is enforced by law, any hunting during closed season is punishable by law and termed as illegal hunting or poaching.

Type of Weapon Used

In wildlife management one of the conservation principles is that the weapon used for hunting should be the one that causes the least damage to the animal and is sufficiently effective so that it hits the target. Given State and Local laws, types of weapon can also vary depending on type, size, sex of game and also the geographical layout of that specific hunting area.

Nuisance Wildlife Management

Nuisance wildlife management is the term given to the process of selective removal of problem individuals or populations of specific species of wildlife. Other terms for the field, include wildlife damage management, wildlife control, and animal damage control to name a few. Some species of wildlife may become habituated to man's presence, causing property damage or risking transfer of disease to humans or pets (zoonosis). Many wildlife species coexist with humans very successfully, such as commensal rodents which have become more or less dependent on humans.



Deer eating tomato plant

Characteristics of Nuisance Species

Typically, species that are most likely to be considered a nuisance by humans have the following characteristics. First, they are adaptable to fragmented habitat. Animals such as Canada geese (*Branta canadensis*) love ponds with low sloping banks leading to lush green grass. Humans love this sort of landscaping too, so it is not surprising that Canada geese have thrived (not to mention the decline in hunting).

Deer-damaged tomato plant has been stripped of developing fruit

Second, these animals are not tied to eating a specific type of food. For example, lynx do not thrive in human impacted environments because they rely so heavily on snowshoe hares. In contrast, raccoons have been very successful in urban landscapes because they can live in attics, chimneys, and even sewers, and can sustain themselves with food gained from trashcans and discarded litter.

Third, successful animals must not pose an obvious significant risk to human health and safety. Animals perceived as grave threats will incur the extreme ire of humans and be under constant threat of humans seeking to eliminate them.

Finally, successful animals in humanized landscapes are often perceived as “cute”, at least until they become so numerous that their preferential status becomes diminished. Many wildlife species have the potential of becoming a “nuisance” species, and whether or not a species is regarded as a pest can be directly correlated with the degree to which that animal can be tolerated by humans. For many people, tree squirrels feeding in their yards or gardens are not a problem; a neighbor may feel that these same squirrels nesting in the attic of their house are a nuisance and a fire hazard, due to their habit of gnawing on electrical cables.

Common Nuisance Species

Common wildlife pests include Armadillos, skunks, foxes, squirrels, snakes, rats, groundhogs, beavers, opossums, raccoons, bats, moles, deer, mice, coyotes, bears, ravens, seagulls, woodpeckers and pigeons. Some of these species are protected by state or federal regulations, such as bears, ravens, bats, deer, woodpeckers, and coyotes, and a permit may be required to control some species.

Wildlife are usually only pests in certain situations, such as when their numbers become “excessive” in a particular area. Human-induced changes in the environment will often result in increased numbers of a species. For example, piles of scrap building material make excellent sites where rodents can nest. Food left out for household pets is often equally attractive to some wildlife species. In these situations, the wildlife have suitable food and habitat and may become a nuisance.

Controlling Wildlife Damage

The primary objective of any control program should be to reduce damage in a practical, humane and environmentally acceptable manner. Wildlife managers and wildlife control operators (WCOs) use control methods based on the habits and biology of the animals causing damage. By using methods matched to the nuisance species, control efforts will be more effective and will serve to maximize safety to the environment, humans and other animals.

Raccoon on a roof.

A key to controlling wildlife damage is prompt and accurate determination of which animal is causing the damage. Even someone with no training or experience can sometimes identify the pest by thoroughly examining the damaged area. Because feeding indications of many wildlife species are similar, other signs – such as droppings, tracks, burrows, nests or food caches – are usually needed to make a positive species identification.

After the wildlife pest is identified, control methods can be chosen appropriate to the animal species involved. Improper control methods may harm but not kill the animal, causing it to become leery of those and other methods in the future. For example, using traps and poison baits improperly or in the wrong situation may teach the animal that the control method is harmful. This may make the animal difficult to control later, even with the correct method.

Four steps lead to a successful nuisance wildlife control program:

- Correctly identify the species causing the problem.
- Alter the habitat, if possible, to make the area less attractive to the wildlife pest.
- Use a control method appropriate to the location, time of year, and other environmental conditions.

- Monitor the site for re-infestation in order to determine if additional control is necessary.

Control Methods

The most commonly used methods for controlling nuisance wildlife around homes and gardens include exclusion, habitat modification, repellents, toxic baits, glue boards, traps and frightening. Wildlife control involves human risks both from possible injury to person and property, but also from zoonotic disease.

Exclusion

Physically excluding an offending animal from the area being damaged or disturbed is often the best and most permanent way to control the problem. Depending upon size of the area to be protected, this control method can range from inexpensive to prohibitively costly.

For example, damage by birds or rabbits to ornamental shrubs or garden plants can be reduced inexpensively by placing bird netting over the plants to keep the pests away. On the other hand, fencing out deer from a lawn or garden can be more costly. Materials needed for exclusion will depend upon the species causing the problem. Large mammals can be excluded with woven wire fences, poly-tape fences, and electric fences; but many communities forbid the use of electric fencing in their jurisdictions. Small mammals and some birds can be excluded with netting, tarp, hardware cloth or any other suitable material; nets come in different weave sizes suitable for different animals to be excluded.

However, exclusion can interfere with the natural movement of wildlife, particularly when exclusion covers large areas of land.

Habitat Modification

Modifying an animal's habitat often provides lasting and cost-effective relief from damage caused by nuisance wildlife. Habitat modification is effective because it limits access to one or more of the requirements for life – food, water or shelter. However, habitat modification, while limiting nuisance wildlife, may also limit desirable species such as songbirds as well.

Rodent- or bat-proofing buildings by sealing cracks and holes prevents these animals from gaining access to suitable habitats where they are not welcome. Storing seed and pet food in tightly closed containers, controlling weeds and garden debris around homes and buildings, and storing firewood and building supplies on racks or pallets above ground level are also practices that can limit or remove the animals' sources of food, water or shelter.

Repellents

Using a repellent that changes the behavior of an animal may lead to a reduction or elimination of damage. Several available repellents, such as objectionable-tasting coatings or odor repellents, may deter wildlife from feeding on plants. Other repellents such as sticky, tacky substances placed on or near windows, trees or buildings may deter many birds and small mammals. Unfortunately, most wildlife soon discover that repellents are not actually harmful, and the animals may quickly become accustomed to the smell, taste or feel of these deterrents.

Chemical repellents applied outdoors will have to be reapplied due to rain or heavy dew, or applied often to new plant growth to be effective. Failure to carefully follow the directions included with repellents can drastically diminish the effectiveness of the product. Some repellents contain toxic chemicals, such as paradichlorobenzene, and are ineffective unless used at hazardous concentrations. Other more natural repellents contain chili pepper or capsaicin extracted from hot peppers.

However, even under the best of conditions, repellents frequently fail to live up to user expectations. The reason for this is twofold. First, many repellents simply don't work. For example, peer-reviewed publications have consistently shown that ultrasonic devices do not drive unwanted animals away. Second, even when the repellent has been shown to work, animals in dire need of food will "hold their nose" and eat anyway because the alternative is essentially death by starvation. Repellents are most successful (referring to products actually demonstrated by peer-reviewed research to be effective) when animals have access to alternative food sources in a different location.

Glue Traps and Boards

Glue traps and boards can be either a lethal or non-lethal method of control. Glue boards can be used to trap small mammals and snakes. Applying vegetable oil will dissolve the glue, allowing for release, but caution must be taken to avoid scratches and bites from the trapped animal.

Live Trapping

Using traps can be very effective in reducing actual population numbers of certain species. However, many species cannot be trapped without a permit. In most cases, homeowners may trap an offending animal within 100 yards of their residence without a permit, however relocation is often illegal.

Traditional live traps such as cage or box traps are easily purchased at most garden centers or hardware stores. These traps allow for safe release of the trapped animal. The release of the animal to another area may be prohibited by state law, or may be regulated by the local Department of Fish and Game. Leghold traps may allow for either release or euthanasia of the trapped animal. Traps such as body-gripping traps, scissor and harpoon traps, as well as rat/mouse snap traps, are nearly always lethal. Knowledge of animal behavior, trapping techniques, and baits is essential for a successful trapping program.(Bornheimer, Shane P. "PreferredWildlifeservices.com" July 2013)

Frightening Devices

Frightening devices such as bells, whistles, horns, clappers, sonic emitters, audio tapes and other sound devices may be quite successful in the short term for repelling an animal from an area. Other objects such as effigies, lights, reflectors and windmills rely on visual stimulation to scare a problem animal away. Often nuisance animals become accustomed to these tactics, and will return later if exposed to these devices daily.

Sonic Nets

In 2013, Dr. John Swaddle and Dr. Mark Hinders at the College of William and Mary created a new method of deterring birds and other animals using benign sounds projected by conventional and directional (parametric) speakers. The initial objectives of the technology were to displace problematic birds from airfields to reduce bird strike risks, minimize agricultural losses due to pest bird foraging, displace nuisance birds that cause extensive repair and chronic clean-up costs, and reduce bird mortality from flying into man-made structures. The sounds, referred to as a "Sonic Net," do not have to be loud and are a combination of wave forms - collectively called "colored" noise - forming non-constructive and constructive interference with how birds and other animals such as deer talk to each other. Technically, the Sonic Nets technology is not a bird or wildlife scarer, but discourages birds and animals from going into or spending time in the target area. The impact to the animals is similar to talking in a crowded room, and since they cannot understand each other they go somewhere else. Early tests at an aviary and initial field trials at a landfill and airfield indicate that the technology is effective and that birds do not habituate to the sound. The provisional and full patents were filed in 2013 and 2014 respectively, and further research and commercialization of the technology are ongoing.

Laws

Before initiating any wildlife control activities, a person must become familiar with applicable federal, state, and local laws. One way to learn these rules is to contact the state's wildlife agency, which is usually responsible for selling hunting and fishing licenses. In general, property owners are permitted to prevent wildlife damage through exclusion and habitat modification, though they may be prohibited from disturbing an occupied nest or den, or directly harming an animal.

Many regulations exist in the United States concerning animal trapping including trap check intervals, usually requiring all traps be checked at least once during a 24-hour period. Some governments permit relocation of wildlife, however humane considerations must be taken into account before relocating wildlife, including population and habitat.

Ethics

There are many ethical considerations in nuisance wildlife management. Some species of wildlife cannot be ethically relocated due to overabundance of competing species, or lack of availability of proper food and habitat. Control during the spring months does run the risk of killing the young by starvation. Proper euthanasia of animals when necessary is also a controversial and sensitive consideration to be taken prior to engaging in nuisance wildlife management, and requires training and certification in some areas of the United States.

Natural Resource Management

Natural resource management refers to the management of natural resources such as land, water, soil, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations (stewardship).

The Tongass National Forest in Alaska is managed by the United States Forest Service

Natural resource management deals with managing the way in which people and natural landscapes interact. It brings together land use planning, water management, biodiversity conservation, and the future sustainability of industries like agriculture, mining, tourism, fisheries and forestry. It recognises that people and their livelihoods rely on the health and productivity of our landscapes, and their actions as stewards of the land play a critical role in maintaining this health and productivity.

Natural resource management specifically focuses on a scientific and technical understanding of resources and ecology and the life-supporting capacity of those resources. Environmental management is also similar to natural resource management. In academic contexts, the sociology of natural resources is closely related to, but distinct from, natural resource management.

History

The emphasis on sustainability can be traced back to early attempts to understand the ecological nature of North American rangelands in the late 19th century, and the resource conservation movement of the same time. This type of analysis coalesced in the 20th century with recognition that preservationist conservation strategies had not been effective in halting the decline of natural resources. A more integrated approach was implemented recognising the intertwined social, cultural, economic and political aspects of resource management. A more holistic, national and even global form evolved, from the Brundtland Commission and the advocacy of sustainable development.

The Bureau of Land Management in the United States manages America's public lands, totaling approximately 264 million acres (1,070,000 km2) or one-eighth of the landmass of the country.

In 2005 the government of New South Wales, established a *Standard for Quality Natural Resource Management*, to improve the consistency of practice, based on an adaptive management approach.

In the United States, the most active areas of natural resource management are wildlife management often associated with ecotourism and rangeland management. In Australia, water sharing, such as the Murray Darling Basin Plan and catchment management are also significant.

Ownership Regimes

Natural resource management approaches can be categorised according to the kind and right of stakeholders, natural resources:

- State property
- Private property
- Common property
- Non-property (open access)
- Hybrid

State Property Regime

Ownership and control over the use of resources is in hands of the state. Individuals or groups may be able to make use of the resources, but only at the permission of the state. National forest, National parks and military reservations are some US examples.

Private Property Regime

Any property owned by a defined individual or corporate entity. Both the benefit and duties to the resources fall to the owner(s). Private land is the most common example.

Common Property Regimes

It is a private property of a group. The group may vary in size, nature and internal structure e.g. indigenous neighbours of village. Some examples of common property are community forests.

Non-property Regimes (Open Access)

There is no definite owner of these properties. Each potential user has equal ability to use it as they wish. These areas are the most exploited. It is said that "Everybody's property is nobody's property". An example is a lake fishery. Common land may exist without ownership, in which case in the UK it is vested in a local authority.

Hybrid Regimes

Many ownership regimes governing natural resources will contain parts of more than one of the regimes described above, so natural resource managers need to consider the impact of hybrid regimes. An example of such a hybrid is native vegetation management in NSW, Australia, where legislation recognises a public interest in the preservation of native vegetation, but where most native vegetation exists on private land.

Stakeholder Analysis

Stakeholder analysis originated from business management practices and has been incorporated into natural resource management in ever growing popularity. Stakeholder analysis in the context of natural resource management identifies distinctive interest groups affected in the utilisation and conservation of natural resources.

There is no definitive definition of a stakeholder as illustrated in the table below. Especially in natural resource management as it is difficult to determine who has a stake and this will differ according to each potential stakeholder.

Different Approaches to who is a Stakeholder:

Source	Who is a stakeholder	Kind of research
Freeman.	"can affect or is affected by the achievement of the organization's objectives"	Business Management
Bowie	"without whose support the organization would cease to exist"	Business Management
Clarkson	"...persons or groups that have, or claim, ownership, rights, or interests in a corporation and its activities, past, present, or future."	Business Management

Grimble and Wellard	"...any group of people, organized or unorganized, who share a common interest or stake in a particular issue or system..."	Natural resource management
Gass et al.	"...any individual, group and institution who would potentially be affected, whether positively or negatively, by a specified event, process or change."	Natural resource management
Buanes et al	"...any group or individual who may directly or indirectly affect—or be affected—...planning to be at least potential stakeholders."	Natural resource management
Brugha and Varvasovszky	"...actors who have an interest in the issue under consideration, who are affected by the issue, or who—because of their position—have or could have an active or passive influence on the decision making and implementation process."	Health policy
ODA	"... persons, groups or institutions with interests in a project or programme."	Development

Therefore, it is dependent upon the circumstances of the stakeholders involved with natural resource as to which definition and subsequent theory is utilised.

Billgrena and Holme identified the aims of stakeholder analysis in natural resource management:

- Identify and categorise the stakeholders that may have influence
- Develop an understanding of why changes occur
- Establish who can make changes happen
- How to best manage natural resources

This gives transparency and clarity to policy making allowing stakeholders to recognise conflicts of interest and facilitate resolutions. There are numerous stakeholder theories such as Mitchell et al. however Grimble created a framework of stages for a Stakeholder Analysis in natural resource management. Grimble designed this framework to ensure that the analysis is specific to the essential aspects of natural resource management.

Stages in Stakeholder Analysis:

1. Clarify objectives of the analysis
2. Place issues in a systems context
3. Identify decision-makers and stakeholders
4. Investigate stakeholder interests and agendas
5. Investigate patterns of inter-action and dependence (e.g. conflicts and compatibilities, trade-offs and synergies)

Application:

Grimble and Wellard established that Stakeholder analysis in natural resource management is most relevant where issued can be characterised as;

- Cross-cutting systems and stakeholder interests
- Multiple uses and users of the resource.
- Market failure
- Subtractability and temporal trade-offs
- Unclear or open-access property rights
- Untraded products and services
- Poverty and under-representation

Case Studies:

In the case of the Bwindi Impenetrable National Park, a comprehensive stakeholder analysis would have been relevant and the Batwa people would have potentially been acknowledged as stakeholders preventing the loss of people's livelihoods and loss of life.

Nepal, Indonesia and Koreas' community forestry are successful examples of how stakeholder analysis can be incorporated into the management of natural resources. This allowed the stakeholders to identify their needs and level of involvement with the forests.

Criticisms:

- Natural resource management stakeholder analysis tends to include too many stakeholders which can create problems in of its self as suggested by Clarkson. "Stakeholder theory should not be used to weave a basket big enough to hold the world's misery."
- Starik proposed that nature needs to be represented as stakeholder. However this has been rejected by many scholars as it would be difficult to find appropriate representation and this representation could also be disputed by other stakeholders causing further issues.
- Stakeholder analysis can be used exploited and abused in order to marginalise other stakeholders.
- Identifying the relevant stakeholders for participatory processes is complex as certain stakeholder groups may have been excluded from previous decisions.

- On-going conflicts and lack of trust between stakeholders can prevent compromise and resolutions.

Alternatives/ Complementary forms of Analysis:

- Social network analysis
- Common pool resource

Management of the Resources

Natural resource management issues are inherently complex they involve the ecological cycles, hydrological cycles, climate, animals, plants and geographetc. All these are dynamic and inter-related. A change in one of them may have far reaching and/or long term impacts which may even be irreversible. In addition to the natural systems, natural resource management also has to manage various stakeholders and their interests, policies, politics, geographical boundaries, economic implications and the list goes on. It is very difficult to satisfy all aspects at the same time. This results in conflicting situations.

After the United Nations Conference for the Environment and Development (UNCED) held in Rio de Janeiro in 1992, most nations subscribed to new principles for the integrated management of land, water, and forests. Although program names vary from nation to nation, all express similar aims.

The various approaches applied to natural resource management include:

- Top-down (command and control)
- Community-based natural resource management
- Adaptive management
- Precautionary approach
- Integrated natural resource management

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Community-based Natural Resource Management

The community-based natural resource management (CBNRM) approach combines conservation objectives with the generation of economic benefits for rural communities. The three key assumptions being that: locals are better placed to conserve natural resources, people will conserve a resource only if benefits exceed the costs of conservation, and people will conserve a resource that is linked directly to their quality of life. When a local people's quality of life is enhanced, their efforts and commitment to ensure the future well-being of the resource are also enhanced. Regional and community based natural resource management is also based on the principle of subsidiarity.

The United Nations advocates CBNRM in the Convention on Biodiversity and the Convention to Combat Desertification. Unless clearly defined, decentralised NRM can result an ambiguous socio-legal environment with local communities racing to exploit natural resources while they can e.g. forest communities in central Kalimantan (Indonesia).

A problem of CBNRM is the difficulty of reconciling and harmonising the objectives of socioeconomic development, biodiversity protection and sustainable resource utilisation. The concept and conflicting interests of CBNRM, show how the motives behind the participation are differentiated as either people-centred (active or participatory results that are truly empowering) or planner-centred (nominal and results in passive recipients). Understanding power relations is crucial to the success of community based NRM. Locals may be reluctant to challenge government recommendations for fear of losing promised benefits.

CBNRM is based particularly on advocacy by nongovernmental organizations working with local groups and communities, on the one hand, and national and transnational organizations, on the other, to build and extend new versions of environmental and social advocacy that link social justice and environmental management agendas with both direct and indirect benefits observed including a share of revenues, employment, diversification of livelihoods and increased pride and identity. CBNRM has raised new challenges, as concepts of community, territory, conservation, and indigenous are worked into politically varied plans and programs in disparate sites. Warner and Jones address strategies for effectively managing conflict in CBNRM.

The capacity of indigenous communities to conserve natural resources has been acknowledged by the Australian Government with the Caring for Country Program. Caring for our Country is an Australian Government initiative jointly administered by the Australian Government Department of Agriculture, Fisheries and Forestry and the Department of the Environment, Water, Heritage and the Arts. These Departments share responsibility for delivery of the Australian Government's environment and sustainable agriculture programs, which have traditionally been broadly referred to under the banner of 'natural resource management'.

These programs have been delivered regionally, through 56 State government bodies, successfully allowing regional communities to decide the natural resource priorities for their regions.

Governance is seen as a key consideration for delivering community-based or regional natural resource management. In the State of NSW, the 13 catchment management authorities (CMAs) are overseen by the Natural Resources Commission (NRC), responsible for undertaking audits of the effectiveness of regional natural resource management programs.

Adaptive Management

The primary methodological approach adopted by catchment management authorities (CMAs) for regional natural resource management in Australia is adaptive management.

This approach includes recognition that adaption occurs through a process of 'plan-do-review-act'. It also recognises seven key components that should be considered for quality natural resource management practice:

- Determination of scale
- Collection and use of knowledge
- Information management
- Monitoring and evaluation
- Risk management
- Community engagement
- Opportunities for collaboration.

Integrated Natural Resource Management

Integrated natural resource management (INRM) is a process of managing natural resources in a systematic way, which includes multiple aspects of natural resource use (biophysical, socio-political, and economic) meet production goals of producers and other direct users (e.g., food security, profitability, risk aversion) as well as goals of the wider community (e.g., poverty alleviation, welfare of future generations, environmental conservation). It focuses on sustainability and at the same time tries to incorporate all possible stakeholders from the planning level itself, reducing possible future conflicts. The conceptual basis of INRM has evolved in recent years through the convergence of research in diverse areas such as sustainable land use, participatory planning, integrated watershed management, and adaptive management. INRM is being used extensively and been successful in regional and community based natural management.

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Frameworks and Modelling

There are various frameworks and computer models developed to assist natural resource management.

Geographic Information Systems (GIS)

GIS is a powerful analytical tool as it is capable of overlaying datasets to identify links. A bush regeneration scheme can be informed by the overlay of rainfall, cleared land and erosion. In Australia, Metadata Directories such as NDAR provide data on Australian natural resources such as vegetation, fisheries, soils and water. These are limited by the potential for subjective input and data manipulation.

Natural Resources Management Audit Frameworks

The NSW Government in Australia has published an audit framework for natural resource management, to assist the establishment of a performance audit role in the governance of regional natural resource management. This audit framework builds from other established audit methodologies, including performance audit, environmental audit and internal audit. Audits undertaken using this framework have provided confidence to stakeholders, identified areas for improvement and described policy expectations for the general public.

The Australian Government has established a framework for auditing greenhouse emissions and energy reporting, which closely follows Australian Standards for Assurance Engagements.

The Australian Government is also currently preparing an audit framework for auditing water management, focussing on the implementation of the Murray Darling Basin Plan.

Other Elements

Biodiversity Conservation

The issue of biodiversity conservation is regarded as an important element in natural resource management. What is biodiversity? Biodiversity is a comprehensive concept, which is a description of the extent of natural diversity. Gaston and Spicer (p. 3) point out that biodiversity is “the variety of life” and relate to different kinds of “biodiversity organization”. According to Gray (p. 154), the first widespread use of the definition of biodiversity, was put forward by the United Nations in 1992, involving different aspects of biological diversity.

Precautionary Biodiversity Management

The “threats” wreaking havoc on biodiversity include; habitat fragmentation, putting a strain on the already stretched biological resources; forest deterioration and deforestation; the invasion of “alien species” and “climate change”(p. 2). Since these threats have received increasing attention from environmentalists and the public, the precautionary management of biodiversity becomes an important part of natural resources management. According to Cooney, there are material measures to carry out precautionary management of biodiversity in natural resource management.

Concrete “policy tools”

Cooney claims that the policy making is dependent on “evidences”, relating to “high standard of proof”, the forbidding of special “activities” and “information and monitoring requirements”. Before making the policy of precaution, categorical evidence is needed. When the potential menace of “activities” is regarded as a critical and “irreversible” endangerment, these “activities” should be forbidden. For example, since explosives and toxicants will have serious consequences to endanger human and natural environment, the South Africa Marine Living Resources Act promulgated a series of policies on completely forbidding to “catch fish” by using explosives and toxicants.

Administration and guidelines

According to Cooney, there are 4 methods to manage the precaution of biodiversity in natural resources management;

1. “Ecosystem based Management” including “more risk-averse and precautionary management”, where “given prevailing uncertainty regarding ecosystem structure, function, and inter-specific interactions, precaution demands an ecosystem rather than single-species approach to management”.

2. “Adaptive management” is “a management approach that expressly tackles the uncertainty and dynamism of complex systems”.

3. “Environmental impact assessment” and exposure ratings decrease the “uncertainties” of precaution, even though it has deficiencies, and

4. “Protectionist approaches”, which “most frequently links to” biodiversity conservation in natural resources management.

Land management

In order to have a sustainable environment, understanding and using appropriate management strategies is important. In terms of understanding, Young emphasises some important points of land management:

- Comprehending the processes of nature including ecosystem, water, soils

- Using appropriate and adapting management systems in local situations
- Cooperation between scientists who have knowledge and resources and local people who have knowledge and skills

Dale et al. (2000) study has shown that there are five fundamental and helpful ecological principles for the land manager and people who need them. The ecological principles relate to time, place, species, disturbance and the landscape and they interact in many ways.It is suggested that land managers could follow these guidelines:

- Examine impacts of local decisions in a regional context, and the effects on natural resources.
- Plan for long-term change and unexpected events.
- Preserve rare landscape elements and associated species.
- Avoid land uses that deplete natural resources.
- Retain large contiguous or connected areas that contain critical habitats.
- Minimize the introduction and spread of non-native species.
- Avoid or compensate for the effects of development on ecological processes.
- Implement land-use and land-management practices that are compatible with the natural potential of the area.

Wildlife Corridor

A wildlife corridor, habitat corridor, or green corridor is an area of habitat connecting wildlife populations separated by human activities or structures (such as roads, development, or logging). This allows an exchange of individuals between populations, which may help prevent the negative effects of inbreeding and reduced genetic diversity (via genetic drift) that often occur within isolated populations. Corridors may also help facilitate the re-establishment of populations that have been reduced or eliminated due to random events (such as fires or disease).

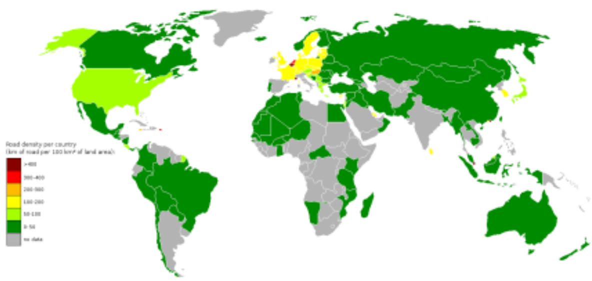
This may potentially moderate some of the worst effects of habitat fragmentation, wherein urbanization can split up habitat areas, causing animals to lose both their natural habitat and the ability to move between regions to use all of the resources they need to survive. Habitat fragmentation due to human development is an ever-increasing threat to biodiversity, and habitat corridors are a possible mitigation.

Purpose

The main goal of implementing habitat corridors is to increase biodiversity. When areas of land are broken up by human interference, population numbers become unstable and many animal and plant species become endangered. By re-connecting the fragments, the population fluctuations can decrease dramatically. Corridors can contribute to three factors that stabilize a population:

- Colonization—animals are able to move and occupy new areas when food sources or other natural resources are lacking in their core habitat.
- Migration—species that relocate seasonally can do so more safely and effectively when it does not interfere with human development barriers.
- Interbreeding—animals can find new mates in neighboring regions so that genetic diversity can increase and thus have a positive impact on the overall population.

Although corridors have been implemented with the assumption that they will increase biodiversity, not enough research has been done to come to a solid conclusion. The case for corridors has been built more on intuition and much less on empirical evidence (Tewksbury et al. 2002). Another factor that needs to be taken into account is what species the corridor is intended for. Some species have reacted more positively to corridors than others.



Map indicating the amount of roads per 100 km^2 of land area for each country

A habitat corridor could be considered as a possible solution in an area where destruction of a natural area has greatly affected its native species. Development such as roads, buildings, and farms can interrupt plants and animals in the region being destroyed. Furthermore, natural disasters such as wildfires and floods can leave animals with no choice but to evacuate. If the habitat is not connected to a safer one, it will ultimately lead to death. A remaining portion of natural habitat is called a remnant, and such portions need to be connected, because when migration decreases, extinction increases (Fleury 1997).

Corridors can be made in two distinct areas—either water or land. Water corridors are called riparian ribbons and usually come in the form of rivers and streams. Land corridors come on a scale as large as wooded strips connecting larger woodland areas. However, they can also be as simple as a line of shrubs along a sidewalk (Fleury 1997). Such areas can facilitate the movement of small animals, especially birds, from tree to tree, until they find a safe habitat to nest in. Not only do minimal corridors aid in the movement of animals, they are also aesthetically pleasing, which can sometimes encourage the community to accept and support them.

Users

Species can be categorized in one of two groups; passage users and corridor dwellers.

Passage users occupy corridors for brief periods of time. These animals use corridors for such events as seasonal migration, dispersal of a juvenile, or moving between parts of a large home range. Usually large herbivores, medium to large carnivores, and migratory species are passage users (Beier & Loe 1992). One common misconception is that the corridor only needs to be wide enough for the passage users to get through. However, the corridor still must be wide enough to be safe and also encourage the animals to use it, even though they do not live out their entire lives in it.

Corridor dwellers can occupy the passage anywhere from several days to several years. Species such as plants, reptiles, amphibians, birds, insects, and small mammals can spend their entire lives in linear habitats. In this case, the corridor must include everything that a species needs to live and breed, such as soil for germination, burrowing areas, and multiple other breeding adults (Beier & Loe 1992).

Types

Habitat corridors can be categorized according to their width. Typically the wider the corridor, the more use it will get from species. However, the width-length ratio, as well as design and quality play just as important of a role in creating the perfect corridor (Fleury 1997). The strip of land will suffer less from edge effects such as weeds, predators, and chemicals if it is constructed properly. The following are three divisions in corridor widths:

- Regional – (>500m wide); connect major ecological gradients such as migratory pathways.
- Sub-regional – (>300m wide); connect larger vegetated landscape features such as ridgelines and valley floors.
- Local – (some <50m); connect remnant patches of gullies, wetlands, ridgelines, etc.

Habitat corridors can also be divided according to their continuity. Continuous corridors are strips that are not broken up, while "stepping stone" corridors are small patches of suitable habitat. When stepping stones are arranged in a line, they form a strip of land connecting two areas, just like a continuous corridor would. Both kinds provide linkages between protected core areas and stimulate or allow species to migrate.

Finally, corridors can come in the form of underpasses or overpasses, which can be very safe for both animals and humans. Many busy highways cross through natural habitats that native species occupy, as well. Large animals such as deer become a hazard when they cross in front of traffic and get hit. An overpass or an underpass serves as a bridge to facilitate the movement of animals across a busy road. Observations have shown that underpasses are actually more successful than overpasses because many times animals are too timid to cross over a bridge in front of traffic and would prefer to be more hidden (Dole et al. 2003).

Overpasses such as this one allow for traffic to continue for human convenience, while allowing wildlife to pass unharmed beneath from place to place.

Costs

Corridors can be expensive to plan out and put into action. For example, Daniel Simberloff et al. states that "a bridge that would maintain a riparian corridor costs about 13 times as much per lane-mile as would a road that would sever the corridor." He also states that maintenance of a corridor would be much more costly than refuges for endangered species. It would simply be easier to move animals between refuges than to buy land, install a corridor, and maintain it. However, where the goal is not just to preserve a few large animal species but to protect biodiversity among all plants and animals, then habitat corridors may be the only option. Corridors are going to be expensive to implement no matter what, but it does depend on the type, location, and size, which can all vary to a great degree. With the lack of field data on the effectiveness, many agencies are not willing to consider putting in corridors.

Monitoring use

It is extremely important for researchers to pay attention to the population changes in animals after a corridor has been implemented to ensure that there are no harmful effects. Researchers can use both mark-recapture techniques and evaluate genetic flow in order to observe how much a corridor is being used. Marking and recapturing animals is more useful when keeping a close eye on individual movement (Mech & Hallet 2001). The only problem is that tagging animals and watching them does not tell anyone whether the migrating individuals are successfully mating with other populations in connected areas of land. On the other hand, genetic techniques can be more effective in evaluating migration and mating patterns.

One of the most important goals of developing a corridor is to increase migration in certain animal species. By looking at a population's gene flow, researchers can understand the genetic consequences of corridors (Mech & Hallett 2001). The migration patterns of an entire population are much more important than the movements of a few individuals. From these techniques, researchers will better understand whether or not habitat corridors are increasing biodiversity.

Stephen Mech and James Hallett introduce an additional reason genetic techniques are more useful; they "measure average migration rates over time, which reveals the effects of fragmentation of several generations and is not as sensitive to current population sizes as mark-recapture studies are." For example, when a population is extremely small, mark-recapture is almost impossible. Clearly, genetic analysis of a species is the best way to determine if animals are actually using corridors to move and reproduce.

Design

According to new research, wildlife corridors are best built with a certain degree of randomness or asymmetry, rather than built symmetrically. The research was conducted at UC Davis.

Wildlife corridors are susceptible to edge effects; habitat quality along the edge of a habitat fragment is often much lower than in core habitat areas. Wildlife corridors are important for large species requiring significant sized ranges; however, they are also vital as connection corridors for smaller animals and plants as well as ecological connectors to provide a *rescue effect*.

Examples

Both the safety of animals and humans can be achieved through the creation of corridors. For example, deer commonly cross roads in order to get to other grazing land. When they are faced with a car coming at them, they freeze; this puts both the deer and the human's life in danger. In Alberta, Canada, an overpass was constructed to keep animals off of the busy highway; the area is part of a national park, so many different creatures roam the area. The top of the bridge is covered in the native grass of the area so that it blends in better and animals will not know the difference. Gates were also put of on either side of the overpass to help guide animals in the right direction (Semrad 2007).

In Southern California, 15 underpasses and drainage culverts were observed to see how many animals used them as corridors. They proved to be especially effective on wide-ranging species such as carnivores, mule deer, small mammals, and reptiles, even though the corridors were not intended specifically for animals. Researchers also learned that factors such as surrounding habitat, underpass dimensions, and human activity also played a role in how much use they got. From this experiment, much was learned about what would constitute a successful habitat corridor (Dole et al. 2003).

In South Carolina, five remnant areas of land were monitored; one was put in the center and four were surrounding it. Then, a corridor was put between one of the remnants and the center. Butterflies that were placed in the center habitat were two to four times more likely to move to the connected remnant rather than the disconnected ones. Furthermore, male holly plants were placed in the center region, and female holly plants in the connected region increased by 70 percent in seed production compared to those plants in the disconnected region. The most impressive dispersal into the connected region, though, was through bird droppings. Far more plant seeds were dispersed through bird droppings in the corridor-connected patch of land (M. 2002).

There have also been positive effects on the rates of transfer and interbreeding in vole populations. A control population in which voles were confined to their core habitat with no corridor was compared to a treatment population in their core habitat with passages that they could use to move to other regions. Females typically stayed and mated within their founder population, but the rate of transfer through corridors in the males was very high. Researchers are not sure why the females did not move about as much, but it is apparent that the corridor effectively transferred at least some of the species to another location for breeding (Aars 1999).

In 2001, a wolf corridor was restored through a golf course in Jasper National Park, Alberta, which enabled wolves to pass through the course. After this restoration, wolves passed through the corridor frequently. This is one of the first demonstrations that corridors are used by wildlife, and can be effective in decreasing fragmentation. Earlier studies had been criticised for failing to demonstrate that corridor restoration leads to a change in wildlife behaviour.

Elephant corridors are narrow strips of land that allow elephants to move from one habitat patch to another. There are 88 identified elephant corridors in India.

In Africa, Botswana houses the largest number of free-roaming elephant herds. Elephants Without Borders (EWB) studies the movement of elephants is working to gain community support of local community corridors, so that elephants and humans can co-exist.

Major Wildlife Corridors

Several artificial wildlife corridors have been created, these include:

- the Paséo Pantera (also known as the MesoAmerican Biological corridor or Paséo del Jaguar)
- the Eastern Himalayan Corridor
- China-Russia Tiger Corridor
- Tandai Tiger Corridor
- the European Green Belt
- The Siju-Rewak Corridor, located in the Garo Hills of India, protects an important population of elephants(thought to be approximately 20% of all the

elephants that survive in the country).This corridor project links together the Siju Wildlife Sanctuary and the Rewak Reserve Forest in Meghalaya State, close to the India-Bangladesh border. This area lies within the meeting place of the Himalayan Mountain Range and the Indian Peninsula and contains at least 139 other species of mammal, including tiger, clouded leopard and the Himalayan black bear.

- the Ecologische Hoofdstructuur is a network of corridors and habitats created for wildlife in the Netherlands

Evaluation

Some animal species are much more apt to use habitat corridors than others depending on what their migration and mating patterns are like. For example, many cases of birds and butterflies successfully using corridors have been observed. Less successful stories have come out of mammals such as deer. How effective a corridor is may simply rely on what species it is directed towards (Tewskbury 2002). Corridors created with birds in mind may be more successful because they are highly migratory to begin with.

Human interference is almost inevitable with the quickly increasing population. The goal behind habitat corridors shows the most hope for solving habitat fragmentation and restoring biodiversity as much as possible. Although there are many positives and negatives, there may be enough positives to continue studying and improving corridors. It is truly difficult to say whether corridors are the solution to increasing biodiversity, because each one must be judged on its own. Each corridor has its own set of standards and goals that may set it apart from another one.

Negatives

A major downfall to habitat corridors is that not much information has been gathered about their success. Due to the lack of positive data, many agencies will not allow corridors to be established because they are unsure of their effectiveness. Another problem with corridors is that they are not as useful as simply preserving land so that it cannot be fragmented. However, it is becoming very difficult to set aside land for nature reserves when road-building, industry, and urban sprawl are all competing for space.

Even if corridors are sought as a solution, it does not necessarily mean that animals will use them. Especially in the case of overpasses, research shows that animals do not like to use them to get to another remnant area of land. Usually overpasses are built over busy highways, and many species are too timid to expose themselves in front of all of the traffic. As more roads and buildings arise, there becomes less space to try to preserve.

Habitat corridors need to be species-specific (not every kind of animal will use every kind of corridor) and corridors can be barriers to some species. For instance plants may use road verges as corridors however some mammals will not cross roads to reach a suitable habitat.

When a corridor is implemented, many times development is so close by, that it becomes difficult to build a wide enough passage. There is usually a very limited amount of space available for corridors, so buffers are not usually added in (Rosenberg 1997). Without a buffer zone, corridors become susceptible to harmful outside factors from city streets, suburb development, rural homes, forestry, cropland, and feedlots.

Unfortunately, another limiting factor to the implementation of corridors is money. With such inconclusive data about the effectiveness of connecting land, it is difficult to get the proper funding. Those who would be in charge of the corridor design and construction would ask such questions as, "What if the corridors affect species negatively?" and "What if they actually aid in the spread of disease and catastrophic events?" Furthermore, there is a possibility that corridors could not only aid in the dispersal of native organisms, but invasive ones, as well (Beier & Loe 1998). If invasive species take over an area they could potentially threaten another species, even to the point of extinction.

Although wildlife corridors have been proposed as solutions to habitat and wildlife population fragmentation, there is little evidence that they are broadly useful as a conservation strategy for all biodiversity in non-developed or less-developed areas, compared to protecting connectivity as the relevant ecological attribute. In other words, corridors may be a useful meme for conservation planning/ers, but the concept has less meaning to wildlife species themselves. Very few wildlife follow easily identified "corridors" or "linkages" (e.g., using computer modeling), instead most species meander and opportunistically move through landscapes during daily, seasonal, and dispersal movement behavior. Wildlife corridors may be useful in highly developed landscapes where they are easily identified as the last remaining and available habitat.

Positives

Habitat corridors may be defenseless against a number of outside influences, but they are still an efficient way of increasing biodiversity. Strips of land aid in the movement of various animal species and pollen and seed dispersal, which is an added benefit to the intended one (M. 2002). For example, when insects carrying pollen or birds carrying seeds travel to another area, plant species effectively get transported, as well.

Another positive aspect of corridors is that they allow both animals and humans to occupy virtually the same areas of land, and thus co-exist where without the corridor this would not be possible. Large animals such as bears can be attracted to residential areas in search of food due to lack of natural resources because of habitat fragmentation. A corridor would provide a passage for the bears to forage in other locations, so that they would not pose as much of a threat to humans.

Wildlife Crossing

Wildlife crossings are structures that allow animals to cross human-made barriers safely. Wildlife crossings may include: underpass tunnels, viaducts, and overpasses (mainly for large or herd-type animals); amphibian tunnels; fish ladders; Canopy bridge (especially for monkeys and squirrels), tunnels and culverts (for small mammals such as otters, hedgehogs, and badgers); green roofs (for butterflies and birds).

Florida State Route 46 was elevated over this underpass. Notice the channeling fences on either side of the crossing.

Wildlife crossings are a practice in habitat conservation, allowing connections or reconnections between habitats, combating habitat fragmentation. They also assist in avoiding collisions between vehicles and animals, which in addition to killing or injuring wildlife may cause injury to humans and property damage.

Similar structures can be used for domesticated animals, such as cattle creeps.

Roads and Habitat Fragmentation

Camel Crossing in Kuwait

Habitat fragmentation occurs when human-made barriers such as roads, railroads, canals, electric power lines, and pipelines penetrate and divide wildlife habitat (Primack 2006). Of these, roads have the most widespread and detrimental impacts (Spellerberg 1998). Scientists estimate that the system of roads in the United States impacts the ecology of at least one-fifth of the land area of the country (Forman 2000). For many years ecologists and conservationists have documented the adverse relationship between roads and wildlife. Jaeger et al. (2005) identify four ways that roads and traffic detrimentally impact wildlife populations: (1) they decrease habitat amount and quality, (2) they increase mortality due to wildlife-vehicle collisions (road kill), (3) they prevent access to resources on the other side of the road, and (4) they subdivide wildlife populations into smaller and more vulnerable sub-populations (fragmentation). Habitat fragmentation can lead to extinction or extirpation if a population's gene pool is restricted enough.

The first three impacts (loss of habitat, road kill, and isolation from resources) exert pressure on various animal populations by reducing available resources and directly killing individuals in a population. For instance, Bennett (1991) found that road kills do not pose a significant threat to healthy populations but can be devastating to small, shrinking, or threatened populations. Road mortality has significantly impacted a number of prominent species in the United States, including white-tailed deer (*Odocoileus virginianus*), Florida panthers (*Puma concolor coryi*), and black bears (*Ursus americanus*) (Clevenger et al. 2001). In addition, habitat loss can be direct, if habitat is destroyed to make room for a road, or indirect, if habitat quality close to roads is compromised due to emissions from the roads (e.g. noise, light, runoff, pollution, etc.) (Jaeger et al. 2005). Finally, species that are unable to migrate across roads to reach resources such as food, shelter and mates will experience reduced reproductive and survival rates, which can compromise population viability (Noss et al., 1996).

In addition to the first three factors, numerous studies have shown that the construction and use of roads is a direct source of habitat fragmentation (Spellerberg 1998). As mentioned above, populations surrounded by roads are less likely to receive immigrants from other habitats and as a result, they suffer from a lack of genetic diversity. These small populations are particularly vulnerable to extinction due to demographic, genetic, and environmental stochasticity because they do not contain enough alleles to adapt to new selective pressures such as changes in temperature, habitat, and food availability (Primack 2006).

The relationship between roads and habitat fragmentation is well documented. One study found that roads contribute more to fragmentation in forest habitats than clear cuts (Reed et al. 1996). Another study concluded that road fragmentation of formerly contiguous forest in eastern North America is the primary cause for the decline of forest bird species and has also significantly harmed small mammals, insects, and reptiles in the United States (Spellerberg 1998). After years of research, biologists agree that roads and traffic lead to habitat fragmentation, isolation and road kill, all of which combine to significantly compromise the viability of wildlife populations throughout the world.

Wildlife-vehicle Collisions

In addition to conservation concerns, wildlife-vehicle collisions have a significant cost for human populations because collisions damage property and injure and kill passengers and drivers. Bruinderink & Hazebroek (1996) estimated the number of collisions with ungulates in traffic in Europe at 507,000 per year, resulting in 300 people killed, 30,000 injured, and property damage exceeding $1 billion. In parallel, 1.5 million traffic accidents involving deer in the United States cause an estimated $1.1 billion in vehicle damage each year (Donaldson 2005).

The conservation issues associated with roads (wildlife mortality and habitat fragmentation) coupled with the substantial human and economic costs resulting from wildlife-vehicle collisions have caused scientists, engineers, and transportation authorities to consider a number of mitigation tools for reducing the conflict between roads and wildlife. Of the currently available options, structures known as wildlife crossings have been the most successful at reducing both habitat fragmentation and wildlife-vehicle collisions caused by roads (Knapp et al. 2004, Clevenger, 2006).

"Animals' Bridge," on the Flathead Indian Reservation in Montana, used by grizzly and black bears, deer, elk, mountain lions, and others

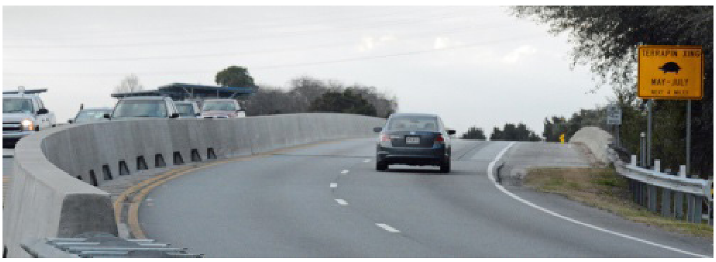
Wildlife crossings are structural passages beneath or above roadways that are designed to facilitate safe wildlife movement across roadways (Donaldson 2005). In recent years, conservation biologists and wildlife managers have advocated wildlife crossings coupled with roadside fencing as a way to increase road permeability and habitat connectivity while decreasing wildlife-vehicle collisions. Wildlife crossing is the umbrella term encompassing underpasses, overpasses, ecoducts, green bridges, amphibian/small mammal tunnels, and wildlife viaducts (Bank et al. 2002). All of these structures are designed to provide semi-natural corridors above and below roads so that animals can safely cross without endangering themselves and motorists.

History and Location

Written reports of rough fish ladders date to 17th-century France, where bundles of branches were used to create steps in steep channels to bypass obstructions. A version was patented in 1837 by Richard McFarlan of Bathurst, New Brunswick, Canada, who designed a fishway to bypass a dam at his water-powered lumber mill. In 1880, the first fish ladder was built in Rhode Island, United States, on the Pawtuxet Falls Dam. As the Industrial Age advanced, dams and other river obstructions became larger and more common, leading to the need for effective fish by-passes.

The first overland wildlife crossings were constructed in France during the 1950s (Chilson 2003). European countries including the Netherlands, Switzerland, Germany, and France have been using various crossing structures to reduce the conflict between wildlife and roads for several decades and use a variety of overpasses and underpasses to protect and re-establish wildlife such as: amphibians, badgers, ungulates, invertebrates, and other small mammals (Bank et al. 2002).

The Humane Society of the United States reports that the more than 600 tunnels installed under major and minor roads in the Netherlands have helped to substantially increase population levels of the endangered European badger. The longest “ecoduct” viaduct, near Crailo in the Netherlands, runs 800 m and spans a highway, railway and golf course.



A Terrapin crossing sign and a highway barrier designed for crossing at the end of the F.J. Torras causeway at St. Simons Island, Georgia, USA (2015)

Wildlife crossings are becoming increasingly common in Canada and the United States. Recognizable wildlife crossings are found in Banff National Park in Alberta, where vegetated overpasses provide safe passage over the Trans-Canada Highway for bears, moose, deer, wolves, elk, and many other species (Clevenger 2007). The 24 wildlife crossings in Banff were constructed as part of a road improvement project in 1978 (Clevenger 2007). In the United States, thousands of wildlife crossings have been built in the past 30 years, including culverts, bridges, and overpasses. These have been used to protect mountain goats in Montana, spotted salamanders in Massachusetts, bighorn sheep in Colorado, desert tortoises in California, and endangered Florida panthers in Florida (Chilson 2003).

Costs and Benefits

The benefits derived from constructing wildlife crossings to extend wildlife migration corridors over and under major roads appear to outweigh the costs of construction and maintenance. One study estimates that adding wildlife crossings to a road project is a 7-8% increase in the total cost of the project (Bank et al. 2002). Theoretically, the monetary costs associated with constructing and maintaining wildlife crossings in ecologically important areas are trumped by the benefits associated with protecting wildlife populations, reducing property damage to vehicles, and saving the lives of drivers and passengers by reducing the number of collisions caused by wildlife.

A study completed for the Virginia Department of Transportation estimated that underpasses for wildlife become cost effective, in terms of property damage, when they prevent between 2.6 and 9.2 deer-vehicle collisions per year, depending on the cost of the underpass. Approximately 300 deer crossed through the underpasses in the year the study took place (Donaldson 2005).

Effectiveness

A number of studies have been conducted to determine the effectiveness of wildlife corridors at providing habitat connectivity (by providing viable migration corridors) and reducing wildlife-vehicle collisions. The effectiveness of these structures appears to be highly site-specific (due to differences in location, structure, species, habitat, etc.) but crossings have been beneficial to a number of species in a variety of locations. Some of the wildlife crossing success stories are detailed below.

Banff National Park

Banff National Park offers one of the best opportunities to study the effectiveness of wildlife crossings because the park contains a wide variety of species and is bisected by a large commercial road called the Trans-Canada Highway (TCH). To reduce the effects of the four-lane TCH, 24 wildlife crossings (22 underpasses and two overpasses) were built to ensure habitat connectivity and protect motorists (Clevenger 2007). In 1996, Parks Canada developed a contract with university researchers to assess the effectiveness of the crossings. The past decade has produced a number of publications that analyze the crossings' impact on various species and overall wildlife mortality.

Wildlife overpass in Banff National Park, Canada

Using a variety of techniques to monitor the crossings over the last 25 years, scientists report that 10 species of large mammals (including deer, elk, black bear, grizzly bear, mountain lion, wolf, moose, and coyote) have used the 24 crossings in Banff a total of 84,000 times as of January 2007 (Clevenger 2007). The research also identified a "learning curve" such that animals need time to acclimate to the structures before they feel comfortable using them. For example, grizzly bear crossings increased from seven in 1996 to more than 100 in 2006, although the actual number of individual bears using the structures remained constant over this time at between 2 and 4 bears (Parks Canada, unpublished results). A similar set of observations was made for wolves, with crossings increasing from two to approximately 140 over the same 10-year period. However, in this case the actual number of wolves in the packs using the crossings increased dramatically, from a low of two up to a high of over 20 individuals. In continuation with these positive results, Clevenger et al. (2001) reported that the use of wildlife crossings and fencing reduced traffic-induced mortality of large ungulates on the TCH by more than 80 percent. Recent analysis for carnivores showed results were not as positive however, with bear mortality increasing by an average of 116 percent in direct parallel to an equal doubling of traffic volumes on the highway, clearly showing no effect of fencing to reduce bear mortality (Hallstrom, Clevenger, Maher and Whittington, in prep). Research on the crossings in Banff has thus shown mixed value of wildlife crossings depending on the species in question.

Parks Canada is currently planning to build 17 additional crossing structures across the TCH to increase driver safety near the hamlet of Lake Louise. Lack of effectiveness of standard fencing in reducing bear mortality demonstrates that additional measures such as wire 'T-caps' on the fence may be needed for fencing to mitigate effectively for bears (Hallstrom, Clevenger, Maher and Whittington, in prep).

Collier and Lee Counties in Florida

Twenty-four wildlife crossings (highway underpasses) and 12 bridges modified for wildlife have been constructed along a 40-mile stretch of Interstate 75 in Collier and Lee counties in Florida (Scott 2007). These crossings are specifically designed to target and protect the endangered Florida panther, a subspecies of mountain lion found in the southeastern United States. Scientists estimate that there are only 80-100 Florida panthers alive in the wild, making them one of the most endangered large mammals in North America (Foster and Humphrey, 1995). The Florida panther is particularly vulnerable to wildlife-vehicle collisions, which claimed 11 panthers in 2006 and 14 panthers in 2007 (Scott 2007).

The Florida Fish and Wildlife Conservation Commission (FWC) has used a number of mitigation tools in an effort to protect Florida panthers and the combination of wildlife crossings and fences have proven the most effective (Scott 2007). As of 2007, no panthers have been killed in areas equipped with continuous fencing and wildlife crossings and the FWC is planning to construct many more crossing structures in the future. The underpasses on I-75 also appeared to benefit bobcats, deer, and raccoons and significantly reduced wildlife-vehicle collisions along the interstate (Foster and Humphrey, 1995).

Underpasses in Southern California

Wildlife crossings have also been important for protecting biodiversity in several areas of southern California. In San Bernardino County, biologists have erected fences along State Route 58 to complement underpasses (culverts) that are being used by the threatened desert tortoise. Tortoise deaths on the highway declined by 93% during the first four years after the introduction of the fences, proving that even makeshift wildlife crossings (storm-drainage culverts in this case) have the ability to increase highway permeability and protect sensitive species (Chilson 2003). Additionally, studies by Haas (2000) and Lyren (2001) report that underpasses in Orange, Riverside, and Los Angeles Counties have drawn significant use from a variety of species including bobcats, coyotes, gray fox, mule deer, and long-tailed weasels. These results could be extremely important for wildlife conservation efforts in the region's Puente Hills and Chino Hills links, which have been increasingly fragmented by road construction (Haas 2000).

Ecoducts, Netherlands

The Netherlands has over 66 wildlife crossings (overpasses and ecoducts) that have been used to protect the endangered European badger, as well as populations of wild boar, red deer, and roe deer. As of 2012, the Veluwe, 1000 square kilometers of woods, heathland and drifting sands, the largest lowland nature area in North Western Europe, contains nine ecoducts, 50 meters wide on average, that are used to shuttle wildlife across highways that transect the Veluwe. The first two ecoducts on the Veluwe were built in 1988 across the A50 when the highway was constructed. Five of the other ecoducts on the Veluwe were built across existing highways, one was built across a two lane provincial road. The two ecoducts across the A50 were used by nearly 5,000 deer and wild boar during a one-year period (Bank et al. 2002). The Netherlands also boasts the world's longest ecoduct-wildlife overpass called the Natuurbrug Zanderij Crailoo (sand quarry nature bridge at Crailo) (Danby 2004). The massive structure, completed in 2006, is 50 m wide and over 800 m long and spans a railway line, business park, river, roadway, and sports complex (Danby 2004). Monitoring is currently underway to examine the effectiveness of this innovative project combining wildlife protection with urban development. The oldest wildlife passage is Zeist West - A 28, opened in 1988.

One of the two wildlife crossings spanning the A50 highway on the Veluwe in the Netherlands

Slaty Creek Wildlife Underpass, Calder Freeway, Black Forest, Australia

Another case study of the effectiveness of wildlife crossings comes from an underpass built to minimize the ecological impact of the Calder Freeway as it travels through the Black Forest in Victoria, Australia. In 1997, the Victorian Government Roads Corporation built Slaty Creek wildlife underpass at a cost of $3 million (Abson & Lawrence 2003). Scientists used 14 different techniques to monitor the underpass for 12 months in order to determine the abundance and diversity of species using the underpass (Abson & Lawrence 2003). During the 12-month period, 79 species of fauna were detected in the underpass (compared with 116 species detected in the surrounding forest) including amphibians, bats, birds, koalas, wombats, gliders, reptiles, and kangaroos (Abson & Lawrence 2003). The results indicate that the underpass could be useful to a wide array of species but the authors suggest that Slaty Creek could be improved by enhanced design and maintenance of fencing to minimise road kill along the Calder Freeway and by attempting to exclude introduced predators such as cats and foxes from the area.

The ARC International Wildlife Crossing Infrastructure Design Competition

In 2010, ARC Solutions - an interdisciplinary partnership - initiated the International Wildlife Crossing Infrastructure Design Competition for a wildlife crossing over Interstate 70 near Denver, Colorado. I-70 is known as Colorado's "Berlin Wall" for wildlife, and designers had to account for many challenges unique to the area, including snow and severe weather, high elevation and steep grades, a six-lane roadway, a bike path, and high traffic volumes, as well as multiple species of wildlife, including lynx.

After receiving 36 submissions from nine countries, a jury of internationally acclaimed experts in landscape architecture, engineering, architecture, ecology and transportation selected five finalists in November 2010 to further develop their conceptual designs for a wildlife crossing structure. In January 2011, the team led by HNTB with Michael Van Valkenburgh & Associates (New York) were selected as the winners. The design features a single 100 m (328 ft) concrete span across the highway that is planted with a variety of vegetation types, including a pine-tree forest and meadow grasses, to attract different species to cross. A modular precast concrete design means that much of the bridge can be constructed offsite and moved into place.

Canopy Bridge in Anamalai Tiger Reserve

Many endangered lion-tailed macaques used to get killed while crossing the highway at Puduthotam in Valparai, South India. Thanks to the efforts of NGOs and the forest department, several canopy bridges were installed, connecting trees on either side of the road. This helped to lower the numbers of lion-tailed macaques killed in the region. The

Environment Conservation Group had initiated a national mission to increase awareness on the importance of adopting roadkill mitigation methods through their mission PATH traveling more than 17,000 kilometers across twenty-two states.

Electric Fence

Electric Fence (or eFence) is a memory debugger written by Bruce Perens. It consists of a library which programmers can link into their code to override the C standard library memory management functions. eFence triggers a program crash when the memory error occurs, so a debugger can be used to inspect the code that caused the error.

Electric Fence is intended to find two common types of programming bugs:

- Overrunning the end (or beginning) of a dynamically allocated buffer
- Using a dynamically allocated buffer after returning it to the heap

In both cases, Electric Fence causes the errant program to abort immediately via a segmentation fault. Normally, these two errors would cause heap corruption, which would manifest itself only much later, usually in unrelated ways. Thus, Electric Fence helps programmers find the precise location of memory programming errors.

Electric Fence allocates at least two pages (often 8KB) for every allocated buffer. In some modes of operation, it does not deallocate freed buffers. Thus, Electric Fence vastly increases the memory requirements of programs being debugged. This leads to the recommendation that programmers should apply Electric Fence to smaller programs when possible, and should never leave Electric Fence linked against production code.

Electric Fence is free software licensed under the GNU General Public License. Last version (2.1.13) was released 2003-12-07.

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3

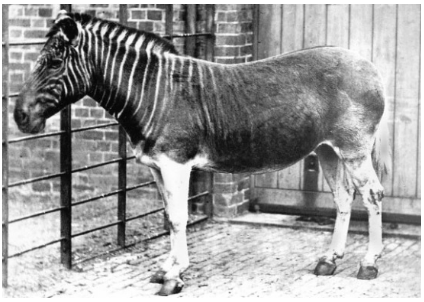
Concerns and Challenges of Wildlife Conservation

Wildlife conservation faces a number of concerns. Some of these are Holocene extinction, poaching, human-wildlife conflict, disturbance and habitat destruction. The capturing of wild animals is known as poaching whereas disturbance is the change in environmental conditions that forces a change in the ecosystem. The topics discussed in the section are of great importance to broaden the existing knowledge on concerns and challenges of wildlife conservation.

Holocene Extinction

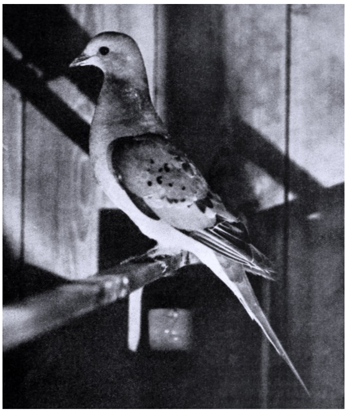
The Holocene extinction, otherwise referred to as the Sixth extinction or Anthropocene extinction, is the ongoing extinction event of species during the present Holocene epoch (11,700 years before AD 2000) mainly due to human activity. The large number of extinctions span numerous families of plants and animals including mammals, birds, amphibians, reptiles and arthropods. Although 875 extinctions occurring between 1500 and 2009 have been documented by the International Union for Conservation of Nature and Natural Resources, with widespread degradation of highly biodiverse habitats such as coral reefs and rainforest, as well as other areas, the vast majority are thought to be undocumented. According to the species-area theory and based on upper-bound estimating, the present rate of extinction may be up to 140,000 species per year, making it the greatest loss of biodiversity since the Cretaceous–Paleogene extinction event.

The dodo, a flightless bird living in Mauritius, became extinct during the mid- to late 17th century after humans destroyed the forests in which they made their homes and introduced mammal species that ate their eggs.



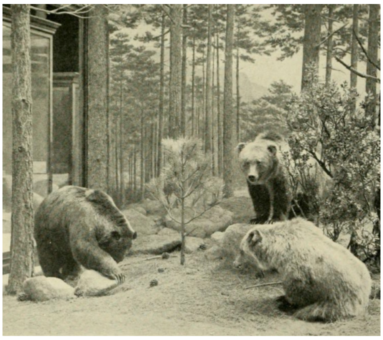
The quagga, originally living in South Africa. became extinct in 1883.

The Holocene extinction includes the disappearance of large land animals known as megafauna, starting between 9,000 and 13,000 years ago, the end of the last Ice Age. Megafauna outside of the African continent, which did not evolve alongside humans, proved highly sensitive to the introduction of new predation, and many died out shortly after early humans began spreading and hunting across the Earth (additionally, many African species have also gone extinct in the Holocene). The extinction of the mammoths allowed grasslands they had maintained through grazing habits to become birch forests. The new forest and the resulting forest fires may have induced climate change. Such disappearances might be the result of the proliferation of modern humans. These extinctions, occurring near the Pleistocene–Holocene boundary, are sometimes referred to as the Quaternary extinction event.



The passenger pigeon became extinct in 1914.

There is no general agreement on where the Holocene, or anthropogenic, extinction begins, and the Quaternary extinction event which includes climate change resulting in the end of the last ice age ends, or if they should be considered separate events at all. Some have suggested that anthropogenic extinctions may have begun as early as when the first modern humans spread out of Africa between 100,000 and 200,000 years ago, which is supported by rapid megafaunal extinction following recent human colonisation in Australia, New Zealand and Madagascar, in a similar way that any large, adaptable predator moving into a new ecosystem would. In many cases, it is suggested even minimal hunting pressure was enough to wipe out large fauna, particularly on geographically isolated islands. Only during the most recent parts of the extinction have plants also suffered large losses.



The Mexican grizzly bear became extinct in 1964.

The ecology of *Homo sapiens* has been noted as being that of an unprecedented "global superpredator" that regularly preys on the adults of other apex predators and has worldwide effects on food webs. Extinctions of species have occurred on every land mass and ocean, with many famous examples within Africa, Asia, Europe, Australia, North and South America, and on smaller islands. Overall, the Holocene extinction can be characterized by the human impact on the environment. The Holocene extinction continues into the 21st century, with overfishing, ocean acidification and the amphibian crisis being a few broader examples of an almost universal, cosmopolitan decline of biodiversity.

The Caribbean monk seal was officially declared extinct in 2008.

It has been suggested human activity has made the period following the mid-20th century different enough from the Holocene to consider it a new geological epoch, known as the Anthropocene, which will be considered for implementation into the timeline of Earth's history by the International Commission on Stratigraphy in 2016.

Human Influence on Extinction

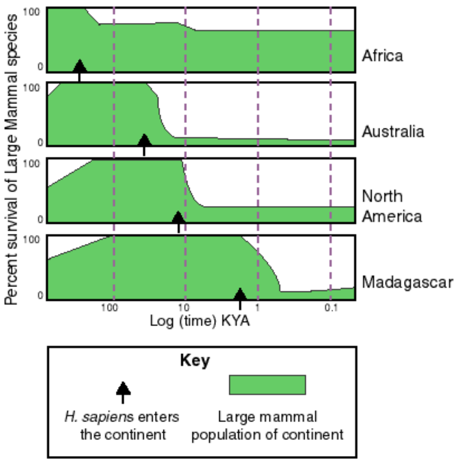
Extinction of animals, plants, and other organisms caused by human actions may go as far back as the late Pleistocene, over 12,000 years ago. There is evidence that abrupt climate change has especially played an enormous role in the extinction of larger mammals. However, while previous mass extinctions were due to natural environmental causes, research shows that wherever on Earth humans have migrated, other species have gone extinct, and human population growth, most prominently in the past two centuries, is regarded as one of the underlying causes of extinction. In terms of how humans have contributed, three major factors include the increased global concentration of greenhouse gases, affecting the global climate; oceanic devastation, such as through overfishing and contamination; and the modification and destruction of vast tracts of land and river systems around the world to meet solely human-centered ends (with 13 percent of Earth's ice-free land surface now used as row-crop agricultural sites, 26 percent used as pastures, and 4 percent urban-industrial areas), thus replacing the original local ecosystems. Other, related human causes of the extinction event include deforestation, hunting, pollution, the introduction in various regions of non-native species, and the widespread transmission of infectious diseases. At present, the rate of extinction of species is estimated at 100 to 1,000 times higher than the "base" or historically typical rate of extinction (in terms of the natural evolution of the planet) and also the current rate of extinction is, therefore, 10 to 100 times higher than any of the previous mass extinctions in the history of Earth. It is also the only known mass extinction of plants.

The abundance of species extinctions considered *anthropogenic*, or due to human activity, have sometimes (especially when referring to hypothesized future events) been collectively called the "Anthropocene extinction". The Anthropocene is a term introduced in 2000. It is now posited by some that a new geological epoch has begun, characterised by the most abrupt and widespread extinction of species since the Cretaceous–Paleogene extinction event 66 million years ago. In *The Future of Life* (2002), E.O. Wilson of Harvard calculated that, if the current rate of human disruption of the biosphere continues, one-half of Earth's higher lifeforms will be extinct by 2100. A 1998 poll conducted by the American Museum of Natural History found that seventy percent of biologists believe that we are in the midst of an anthropogenic extinction. Numerous scientific studies—such as a 2004 report published in *Nature*, and papers authored by the 10,000 scientists who contribute to the IUCN's annual Red List of threatened species—have since reinforced this conviction.

Extinction of the Megafauna in the Late-Pleistocene

The evidence of all previous extinctions is geological in nature, and shorter geological time scale is of the order of several hundred thousand to several million years. Even extinctions caused by instantaneous events such as the impact of the asteroid in Chicxulub, which is currently the best example, extend the equivalent of many human lives, due to complex ecological interactions that were triggered by the event.

Three hypotheses have been proposed to explain the extinction of megafauna in the late Pleistocene. Of these, only two have much scientific credibility. Although Ross McPhee proposed that a hyper-disease may have been the cause of the extinction, a study by Lyons *et al.*, demonstrated conclusively that a hyperdisease was unlikely to have caused the extinction. The two main theories to the extinction are climate change and human hunting. The climate change theory has suggested that a change in climate near the end of the late Pleistocene stressed the megafauna to the point of extinction. Some scientists favor abrupt climate change as the catalyst for the extinction of the mega-fauna at the end of the Pleistocene, but there are many who believe increased hunting from early modern humans also played a part, with others even suggesting that the two interacted. In the Americas, a controversial explanation for the shift in climate is presented under the Younger Dryas impact hypothesis.



The % of megafauna on different land masses over time, with the arrival of humans indicated.

Megafauna was once found on every continent of the world and large islands such as New Zealand and Madagascar, but is now almost exclusively found on the continent of Africa, with notable comparisons on Australia and the islands previously mentioned experiences population crashes and trophic cascades shortly after the earliest human settlers. It has been suggested that the African megafauna survived as they evolved alongside humans. The timing of South American megafaunal extinction does not appear to correspond to human arrival, although the possibility of whether human activity at the time may have impacted the global climate enough to cause such an extinction has been suggested.

It has been noted, in the face of such evidence, *Homo sapiens* is unique in its ecology as an unprecedented 'global superpredator', regularly preying on large numbers of fully grown terrestrial and marine apex predators, and with a great deal of influence over food webs and climatic systems worldwide.

Anthropogenic Impact on Climate During the Holocene

In order to constitute the Holocene as an extinction event, scientists must determine exactly when anthropogenic greenhouse gas emissions began to measurably alter natural atmospheric levels at a global scale and when these alterations caused changes to global climate. Employing chemical proxies from Antarctic ice cores, researchers have estimated the fluctuations of carbon dioxide (Co2) and methane gases (CH4) in the earth's atmosphere for the late Pleistocene and Holocene epochs. Based on these studies, general argumentation of when the peak of the Anthropocene occurred pertains to the timeframe within the previous two centuries; typically beginning with the Industrial Revolution, when greenhouse gas levels were recorded by contemporary methods at its highest. However, scientists that are employing a variance of archaeological and paleoecological data argue that the processes contributing to substantial human modification of the environment spanned many thousands of years ago on a global scale and thus, not originating as early as the Industrial Revolution. Gaining popularity on his uncommon hypothesis, Palaeoclimatologist William Ruddiman in 2003, stipulated that in the early Holocene 11,000 years ago, atmospheric carbon dioxide and methane levels has fluctuated at a different pattern than the Pleistocene epoch before it. He argued that the patterns of the significant decline of CO_2 levels during the last ice age of the Pleistocene inversely correlates to the Holocene where there has been dramatic increases of CO_2 around 8000 years ago and CH_4 levels 3000 years after that. The correlation between the downfall of CO_2 in the Pleistocene and the uprising of it during the Holocene implies that the causation of this spark of greenhouse gases into the atmosphere are due to the growth of human agriculture during the Holocene such as the anthropogenic expansion of land and irrigation.

Recent extinctions described are well-documented, but the nomenclature used varies. The term Anthropocene is a term that is used by few scientists, and some commentators may refer to the current and projected future extinctions as part of a longer Holocene extinction. The Holocene–Anthropocene boundary is contested, with some commentators asserting significant human influence on climate for much of what is normally regarded as the Holocene Epoch. Other commentators place the Holocene–Anthropocene boundary at the industrial revolution while also saying that “Formal adoption of this term in the near future will largely depend on its utility, particularly to earth scientists working on late Holocene successions.”

Agriculture

Human civilization flourished in accordance to the efficiency and intensification of prevailing subsistence systems. Local communities that acquire more subsistence strategies increased in number to combat competitive pressures of land utilization. Therefore, the Holocene developed competition on the basis of agriculture. The growth of agriculture has then introduced newer means of climate change and pollution.

Recent investigations about hunter-gatherer landscape burning has a major implication for the current debate about the timing of the Anthropocene and the role that humans may have played in the production of greenhouse gases prior to the Industrial Revolution. Studies on early hunter-gatherers raises questions about the current use of population size or density as a proxy for the amount of land clearance and anthropogenic burning that took place in preindustrial times. Scientists have questioned the correlation between population size and early territorial alterations. Ruddiman and Ellis’ research paper in 2009 makes the case that early farmers involved in systems of agriculture used more land per capita than growers more later in the Holocene, who intensified their labor to produce more food per unit of area; arguing that agricultural involvement in rice production implemented thousands of years ago by relatively small populations have created significant environmental impacts through large-scale means of deforestation.

While a number of human-derived factors are recognized as potentially contributing to rising atmospheric concentrations of CH_4 and CO_2, deforestation and territorial clearance practices associated with agricultural development may be contributing most to these concentrations globally.

Climate

Climate change in the Early Holocene was distinguished prior to the last glacial maximum 15,000 years ago which then started the current period of the glacial retreat where climate started to increase significantly 11,000 years ago. The Holocene Epoch contained a vast number of temperature fluctuations that can be dated from the warm period of the *Holocene Climatic Optimum* in 5000 to 3000 BC that consisted of temperatures that were 1-2 degrees Celsius warmer than today to the more recent emergence of the *Industrial Revolution*. During this period, came the development of ancient civilizations of the earliest *Homo sapiens* and the growth of agriculture due to the increase of tropical regions. Deepening the understanding of the anthropogenic impact in the early Holocene is a vital factor for analyzing interglacial climate instability due to their involvement in producing of atmospheric carbon dioxide.

Methodologies of the Holocene Climatic Optimum

To undermine the present and future human-induced climatic changes, climatologists and paleontologists have correlated the increases of temperatures with the variations of solar radiation exposed to certain latitudinal earth bands during the Early Holocene. Thus, believing that the Holocene warming was solar in origin where only certain parts of the world experienced warmer climates during seasons such as summer. Moreover, scientists have conducted numerous oceanic sediments that can be dated back to the *Holocene Climatic Optimum*, and discovered drastic increases of sea-levels and their sea-level highstands. This evidence of drastic increases of sea levels indicates that the deterioration of ice cores is crucial to understanding how the Holocene Climatic Optimum began and how it played as one of the major transgressions during the Holocene Maximum. As speculations of how the Holocene Climatic Optimum began remain scientifically unclear, impurities in gaseous chemistry inside these ice cores have been conducted as a valuable method of obtaining evidence of abnormal temperature fluctuations. The Nile River showed to have a greater volume and much larger in the Holocene than what it is today and the Sahara to have been more fertile. This in turn, led many anthropogenic hypotheses to claim that more tropical territories encouraged agricultural processes. However, there is greater complexity as to whether such changes are heavily caused by anthropogenic effects on climate because of limited methods that can directly identify an empirical correlation.

Prehistoric Extinctions (60,000 BCE-3500 BCE)

Although significant debate exists as to how much human predation and indirect effects contributed to prehistoric extinctions, certain population crashes have been directly correlated with human arrival.

Australia

Australia was once home to a large assemblage of megafauna, with many parallels to those found on the African continent today. Australia's fauna is characterised by primarily marsupial mammals, and many reptiles and birds, all existing as giant forms until recently. Humans arrived on the continent very early, about 50,000 years ago. The extent human arrival contributed is controversial; climatic drying of Australia 40,000-60,000 years ago was an unlikely cause, as it was less severe in speed or magnitude than previous regional climate change which failed to kill off megafauna.

Due to the older timeframe and the soil chemistry on the continent, very little subfossil preservation evidence exists relative to elsewhere. However, continent-wide extinction of all genera weighing over 100 kilograms, and six of seven genera weighing between 45 and 100 kilograms occurred around 46,400 years ago (4,000 years after human arrival) and the fact that megafauna survived until a later date on the island of Tasmania following the establishment of a land bridge suggest direct hunting or anthropogenic ecosystem disruption such as fire-stick farming as likely causes. The first evidence of direct human predation leading to extinction in Australia was published in 2016.

Genyornis newtoni, a 7 foot tall flightless bird. Evidence of egg cooking in this species is the first evidence of megafaunal hunting by humans on Australia.

- *Dromornithidae,* an entire family of giant birds. Though around the size of emus, they are actually more related to ducks and other waterfowl. Analysis of burned eggshells in *Genyornis newtoni*, which stood around 7 feet tall, suggested human consumption. As of yet, this is the most reliable direct evidence of human predation on Australian megafauna.

- *Diprotodon,* giant relatives of wombats
- *Zygomaturus,* a marsupial superficially resembling a rhinoceros
- *Hulitherium,* a large marsupial herbivore
- *Phascolonus,* a giant wombat
- *Palorchestes azael,* a marsupial "tapir"
- A highly diverse assemblage of kangaroos. These include giant species from several genus, including *Macropus titan, Simosthenurus, Sthenurus* and *Protemnodon*. Other unique kangaroo radiations include *Procoptodon goliah,* a hoof-toed giant short-faced kangaroo, and *Propleopus oscillans,* an omnivorous kangaroo
- *Wonambi,* a five-to-six-metre-long Australian constrictor snake
- *Thylacoleo carnifex,* a lioness-sized marsupial carnivore
- *Varanus priscus,* a giant predatory monitor lizard
- *Zaglossus hacketti,* a giant species of echidna
- Quinkana, a five-to-six metre-long predatory terrestrial crocodile

Extinctions in Australia continued from original settlement until today in both plants and animals, whilst many more animals and plants have declined or are endangered.

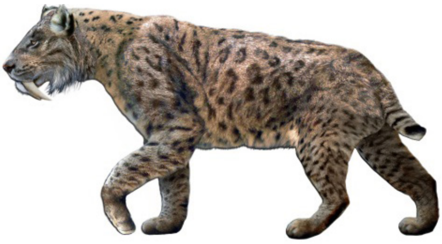
North and South America

There has been a debate as to the extent to which the disappearance of megafauna at the end of the last glacial period can be attributed to human activities by hunting, or even by slaughter of prey populations. Discoveries at Monte Verde in South America and at Meadowcroft Rock Shelter in Pennsylvania have caused a controversy regarding the Clovis culture. There likely would have been human settlements prior to the Clovis Culture, and the history of humans in the Americas may extend back many thousands of years before the Clovis culture. The amount of correlation between human arrival and megafauna extinction is still being debated: for example, in Wrangel Island in Siberia the extinction of dwarf woolly mammoths (approximately 2000 BCE) did not coincide with the arrival of humans, nor did megafaunal mass extinction on the South American continent, although it has been suggested climate changes induced by anthropogenic effects elsewhere in the world may have contributed.

Reconstructed woolly mammoth bone hut, based on finds in Mezhyrich.

Comparisons are sometimes made between recent extinctions (approximately since the industrial revolution) and the Pleistocene extinction near the end of the last glacial period. The latter is exemplified by the extinction of large herbivores such as the woolly mammoth and the carnivores that preyed on them. We know that humans of this era actively hunted the mammoth and the mastodon but it is not known if this hunting was the cause of the subsequent massive ecological changes, widespread extinctions and climate changes.

The ecosystems encountered by the first Americans had not been exposed to human interaction, and may have been far less resilient to human made changes than the ecosystems encountered by industrial era humans. Therefore, the actions of the Clovis people, despite seeming insignificant by today's standards could indeed have had a profound effect on the ecosystems and wild life which was entirely unused to human influence.



Smilodon fatalis

The following species, among many others, became extinct in this period.

- *Doedicurus,* a giant armadillo
- American cheetah
- American lion
- *Holochilus primigenus*
- Pygmy mammoth, woolly mammoth and the local Columbian mammoth
- Mastodons
- *Eremotherium*
- *Smilodon*, sabre toothed cats

- Teratorns, a group of birds that include some of the largest flying animals of all time

Caribbean

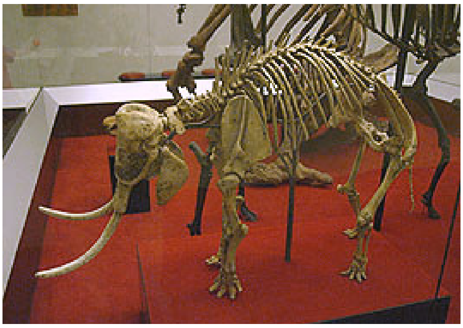
Human arrival around 6,000 years ago is correlated with the extinction of many species. Examples include:

- Many different genera of ground and arboreal sloths across all islands. These sloths were generally smaller than those found on the South American continent. *Megalocnus* were the largest genus at up to 90 kg, *Acratocnus* were medium-sized relatives of modern two-toed sloths endemic to Cuba, *Imagocnus* also of Cuba, *Neocnus* and many others.
- Giant hutias
- Cuban coney
- *Brotomys*
- Cuban giant owl

Pacific Islands

Recent research, based on archaeological and paleontological digs on 70 different islands, has shown that numerous species became extinct as people moved across the Pacific, starting 30,000 years ago in the Bismarck Archipelago and Solomon Islands. It is currently estimated that among the bird species of the Pacific some 2000 species have gone extinct since the arrival of humans, representing a 20% drop in the biodiversity of birds worldwide. Among the extinctions were:

- *Sylviornis*, a giant galliform bird from New Caledonia
- Mekosuchine crocodiles from New Caledonia, Fiji and Samoa.
- Meiolaniid turtles on Lord Howe Island and New Caledonia
- "Gavialis" papuensis, a marine crocodilian from the Solomon Islands.



Mammuthus creticus,a dwarf elephant once endemic to Crete. It was one of many species of small elephants found on islands in the Mediterranean.

Mediterranean Islands

- Pygmy hippos of Cyprus (*Phanourios minutus*), Crete (*Hippopotamus creutzburgi*), Malta (*H. melitensis*) and Sicily (*H. pentlandi*)
- Balearic Islands cave goat (*Myotragus balearicus*) of Majorca and Minorca
- A diverse assemblage of dwarf elephants of several islands, including Cyprus (*Elephas cypriotes*), Sicily, Malta (*E. falconeri*) and Crete (*Mammuthus creticus*)
- Giant swan (*Cygnus falconeri*) of Malta
- Giant dormice: Minorcan giant dormouse, Majorcan giant dormouse
- Sardinian pika of Sardinia and Corsica

Extinctions into the Common Era (3500 BCE-1500 CE)

More recent settlement of isolated land masses where megafauna continued to survive almost immediately resulted in their extinction. Calculations suggest this occurred even if only a small number of animals were hunted. It has been suggested this contemporary evidence supports the theory that humans were capable of causing or at least contributing to the extinctions of the Quaternary extinction event.

Afro-Eurasian Mainland

- Atlas wild ass (*Equus africanus atlanticus*)
- North African aurochs (*Bos primigenius africanus*)
- Indian aurochs (*Bos primigenius namadicus*)
- North African elephant (*Loxodonta africana pharaoensis*)

Hawaiian Islands

The first settlers are thought to have arrived in the islands between 300 and 800 CE, with European arrival in the 16th century. Hawaii is notable for its endemism of plants, birds, insects, mollusks and fish; 30% of its organisms are endemic. Many of its species are endangered or have gone extinct, primarily due to accidentally introduced species and livestock grazing. Over 40% of its bird species have gone extinct, and it is the location of 75% of extinctions in the United States.

Extinction has increased in Hawaii over the last 200 years and is relatively well documented, with extinctions among native snails used as estimates for global extinction rates.

- The moa-nalos, grazing ducks from Hawaii.
- The nēnē-nui, or woodwalking goose, a large species of goose that once inhabited the island of Maui.
- Kauaʻi finch, a large finch
- *Synemporion keana*, a vesper bat

Indian Ocean Islands

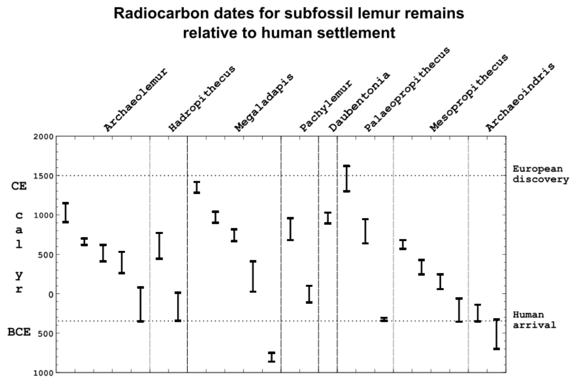
Starting circa 1500 years ago, a number of species became extinct upon human settlement of the islands, including:

- Several species of giant tortoise on the Seychelles and Mascarene Islands, including *Cylindraspis* and *Meiolania platyceps*
- *Aldabrachampsus,* a Crocodyliform found on the Aldabra Atoll

Madagascar

Within 500 years of the arrival of humans between 2,500-2,000 years ago, nearly all of Madagascar's distinct, endemic and geographically isolated megafauna became extinct. The largest animals, of more than 150 kg, were extincted very shortly after the first human arrival, with large and medium-sized species dying out after prolonged hunting pressure from an expanding human population moving into more remote regions of the island around 1000 years ago. Smaller fauna experienced initial increases due to decreased competition, and then subsequent declines over the last 500 years. All fauna weighing over 10 kg died out. The primary reasons for this are human hunting and habitat loss from early aridification, both of which persist and threaten Madagascar's remaining taxa today.

Megaladapis edwardsi, a large arboreal lemur, being one of many of the diverse assemblage of megafauna recently wiped out by human activity on Madagascar.



Radiocarbon dating of multiple subfossil specimens shows that now extinct giant lemurs were present in Madagascar until after human arrival.

- Eight or more species of elephant birds, giant flightless ratites in the genera *Aepyornis* and *Mullerornis*.
- 17 species of lemur, known as giant, subfossil lemurs. Some of these lemurs typically weighed over 150 kg, and fossils have provided evidence of human butchery on many species.
    - Giant aye-aye (*Daubentonia robusta*)
    - Sloth lemurs, including chimpanzee-sized *Palaeopropithecus* and gorilla-sized *Archaeoindris*
    - Koala lemurs (*Megaladapis*), a koala-like, orangutan-sized arboreal lemur
    - Monkey lemurs, most terrestrial of lemurs, often compared to baboons or macaques.
    - *Pachylemur*, a larger, more robust genus of ruffed lemurs
- Giant fossa
- Voay, a terrestrial giant dwarf crocodile
- *Plesiorycteropus*, a genus containing two species of superficially Aardvark-like digging mammal unlike anything alive today
- Three species of Malagasy hippopotamus
- Malagasy crowned eagle (*Stephanoaetus mahery*), a giant bird of prey
- Local giant tortoises of genus *Geochelone*, including *Aldabrachelys abrupta* and *Aldabrachelys grandidieri*. The latter were important seed dispersers for endemic baobab trees.

Recent Extinctions - 1500 Onwards

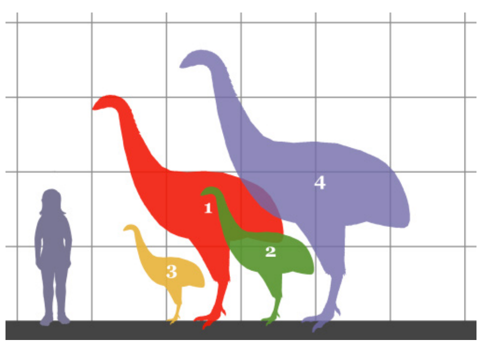
One scientist estimates the current extinction rate may be 10,000 times the background extinction rate. Nevertheless, most scientists predict a much lower extinction rate than this outlying estimate. Stuart Pimm stated "the current rate of species extinction is about 100 times the natural rate" for plants. Mass extinctions are characterized by the loss of at least 75% of species within a geologically short period of time.

In a pair of studies published in 2015, extrapolation from observed extinction of Hawaiian snails led to the conclusion that 7% of all species on Earth may have been lost already.

Megafaunal extinctions continue into the 21st century. Modern extinctions are more directly attributable to human influences. Extinction rates are minimized in the popular imagination by the survival of captive populations of animals that are *extinct in the wild* (such as the Père David's deer, Hawaiian crow) and by marginal survivals of highly publicized megafauna that are *ecologically extinct* (such as the giant panda, Sumatran rhinoceros, North American black-footed ferret). However, the Holocene can also be characterisied by widespread extinctions among arthropods, widespread *local* extinctions of populations of species that still exist elsewhere (such as the extinction of gray whales in the Atlantic and of the leatherback sea turtle in Malaysia) and by universal declines in range and population of various animal and plant species throughout all of the world.

The IUCN characterises 'recent' extinction as those that have occurred past the cut-off point of 1500. The extinct species listed below are not comprehensive, but are some of the most famous examples.

New Zealand



A size comparison between 4 recently extinct New Zealand moa species and a human. **1.** *Dinornis novaezealandiae* **2.** *Emeus crassus* **3.** *Anomalopteryx didiformis* **4.** *Dinornis robustus*

New Zealand is characterised by its geographic isolation and island biogeography, and had been isolated from mainland Australia for 80 million years. It was the last large land mass to be colonised by humans. The arrival of Polynesian settlers circa 12th century resulted in the extinction of all of the islands' megafaunal birds within several hundred years. The Polynesians also introduced the Polynesian rat. This may have put some pressure on other birds but at the time of early European contact (18th Century) and colonisation (19th Century) the bird life was prolific. With them, the Europeans brought ship rats, possums, cats and mustelids which decimated native bird life, some of which had adapted flightlessness and ground nesting habits and others had no defensive behavior as a result of having no extant endemic mammalian predators. The kakapo, the world's biggest parrot, which is flightless, now only exists in managed breeding sanctuaries and NZ's national emblem, the kiwi, is on the endangered bird list.

Extinctions include, among many others:

- Eleven species of moa, giant flightless ratites. The last moa became extinct within 200 years of the arrival of human settlers.
- The giant Haast's eagle, *Harpagornis*
- Two species of giant flightless predatory adzebills.
- Finsch's duck, a large, flightless duck

Other Notable Recent Extinctions

Mammals

Javan tiger pictured 1938.

Some examples of modern extinctions of "charismatic" mammal fauna include:

- Eurasian aurochs (1627), a wild cow that was domesticated to form modern cattle.
- Steller's sea cow (1768), a large sirenian driven to extinction across its prehistoric range across the North Pacific by hunting. The last populations, reduced to the Commander Islands, were driven to extinction 27 years after their discovery by Europeans in 1741 (where they may have numbered at 2000) after heavy hunting.
- Sardinian pika (1774) primitive lagomorph native to the Mediterranean islands of Sardinia and Corsica

- Bluebuck, a species of antelope. Despite already being uncommon by the time of European discovery, habitat conversion for agriculture and hunting resulted in its extinction by 1800.
- Atlas bear (1870s)
- Falkland Islands wolf (1876)
- Quagga (1883), zebra subspecies, Southeast Africa. Recent attempts have been made by the Quagga Project to selectively breed Burchell's zebras to superficially resemble quaggas.
- Tarpan, a European wild horse. Although extinct in the wild by 1890, the last captive animal died in 1909.
- Thylacine (1936) or Tasmanian tiger, *Thylacinus cynocephalus*, a marsupial carnivore persecuted by farmers and the government for preying on livestock.
- Caribbean monk seal (1950s)
- Japanese sea lion (1970s)
- Pyrenean ibex (2000). Attempts were made to clone the species shortly after its extinction, and despite brief success the only surviving foetus died after 7 minutes.
- Yangtze dolphin, extinct 2006
- The closely related Bali tiger (1937) and Javan tiger (1970s)
- Eastern cougar (2011) a subspecies of North American cougar
- Western black rhinoceros (2011), a subspecies

Birds

The Po′ouli, a species of Hawaiian honeycreeper, and the only member of its genus. After severe habitat loss and predation from invasive species such as the small Asian mongoose and feral pigs and rats, the last individual died in 2004 after unsuccessful attempts at captive breeding.

Many birds have become extinct as a result of human activity, especially birds endemic to islands, including many flightless birds birds). Notable extinct birds include:

- Many species of birds on the Mascarene Islands, including the giant flightless pigeons known as the dodo of Mauritius (1662) and the Rodrigues solitaire (1778) and the unrelated Réunion solitaire, which was a flightless ibis (early 1800s)
- Giant owls such as *Tyto pollens*
- Great auk (1852) once highly abundant flightless auk around the North Atlantic
- Passenger pigeons (1914) of North America, once so abundant that accounts suggest their flocks took days to pass
- The Carolina parakeet (1918) of the American southeast
- Ivory-billed woodpecker (2000)

Ten species or subspecies of birds have disappeared from the Hawaiian islands since the 1980s, primarily due to invasive species and habitat loss. These include:

- The entire Mohoidae songbird family, including four species of □ō□ō such as the Hawai□i and Kaua□i □ō□ōs and the kioea
- All members of the group Nukupu‘u. Two species became extinct in the 1990s.
- All members of the finch genus Akialoa.
- Kāma□o
- Po□ouli, a single species of Hawaiian honeycreeper within its own genus.

Plants

The golden toad of Costa Rica, extinct since around 1989. Its disappearance has been attributed to a confluence of several factors, including El Niño warming, fungus, and the introduction of invasive species.

Contemporary Crises

Peter Raven, past president of the American Association for the Advancement of Science (AAAS), states in the foreword to their publication *AAAS Atlas of Population and Environment*: “We have driven the rate of biological extinction, the permanent loss of species, up several hundred times beyond its historical levels, and are threatened with the loss of a majority of all species by the end of the 21st century."

189 countries which are signatory to the Convention on Biological Diversity (Rio Accord) have committed to preparing a Biodiversity Action Plan, a first step at identifying specific endangered species and habitats, country by country.

Various species are predicted to become extinct in the near future.

According to the World Wildlife Fund's 2016 Living Planet Index, 67% of the world's wildlife could disappear by 2020 unless measures are taken to reduce humanity's impact. Research by the WWF and the Zoological Society of London indicates that the destruction of wild habitats, hunting and pollution are to blame for this trend.

Amphibian Crisis

The decline of amphibian populations has also been identified as an indicator of environmental degradation. As well as habitat loss, introduced predators and pollution, Chytridiomycosis, a fungal infection thought to have been accidentally spread by human travel, has caused severe population drops of several species of frogs, including (among many others) the extinction of the golden toad in Costa Rica and the Gastric-brooding frog in Australia. Many other amphibian species now face extinction, including the reduction of Rabb's fringe-limbed treefrog to an endling, and the extinction of the Panamanian golden frog in the wild. Chytrid fungus has spread across Australia, New Zealand, Central America and Africa, including countries with high amphibian diversity such as cloud forests in Honduras and Madagascar. *Batrachochytrium salamandrivorans* is a similar infection currently threatening salamanders. Amphibians are now the most endangered vertebrate group, having existed for more than 300 million years through three other mass extinctions.

Mass Bat Deaths

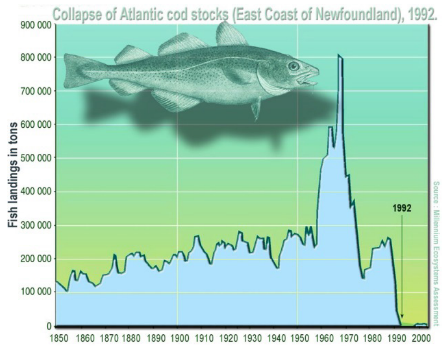
Millions of bats in the US have been dying off since 2012 due to a fungal infection spread from European bats, which appear to be immune. Population drops have been as great as 90% within five years, and extinction of at least one bat species is predicted. There is currently no form of treatment, and such declines have been described as "unprecedented" in bat evolutionary history by Alan Hicks of the New York State Department of Environmental Conservation.

Global Warming

Global warming is widely accepted as being a contributor to extinction worldwide, in a similar way that previous extinction events have generally included a rapid change in global climate and meteorology. It is also expected to disrupt sex ratios in many reptiles which have temperature-dependent sex determination.

Degradation of Marine Habitats

Rising levels of carbon dioxide are resulting in influx of this gas into the ocean, increasing its acidity. Marine organisms which possess Calcium Carbonate shells or exoskeletons experience physiological pressure as the carbonate reacts with acid. This is already resulting in coral bleaching on various coral reefs worldwide, which provide valuable habitat for very high biodiversity. Marine gastropods, bivalves and other invertebrates are also affected, as are any organisms that feed on them.



The collapse of Atlantic cod off the coast of Newfoundland in 1992 as a result of overfishing. The population never recovered, completely altering the ecosystem and rendering the species locally extinct.

Fishing has had a devastating effect on marine organism populations for several centuries even before the explosion of destructive and highly effective fishing practices like trawling. Humans are unique among predators in that they regularly predate on other adult apex predators, particularly in marine environments; bluefin tuna and various sharks in particular are particularly vulnerable to predation pressure from human fishing.

Pollinator Decline

The term pollinator decline refers to the reduction in abundance of insect and other animal pollinators in many ecosystems worldwide beginning at the end of the twentieth century, and continuing into the present day.

Poaching

Poaching has traditionally been defined as the illegal capturing of wild animals, usually associated with land use rights.

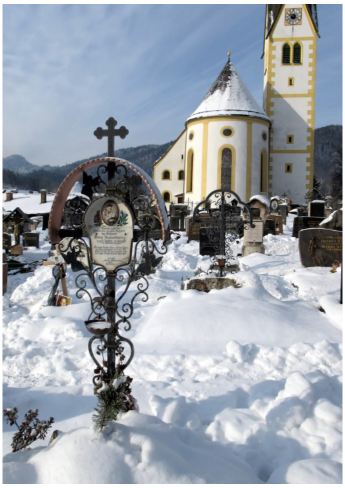
According to Encyclopedia Britannica, poaching was performed by impoverished peasants for subsistence purposes and a supplement for meager diets. Poaching was as well set against the hunting privileges of nobility and territorial rulers. By contrast, stealing domestic animals (as in cattle raiding, for example) classifies as theft, not as poaching.

Since the 1980s, the term "poaching" has also referred to the illegal harvesting of wild plant species. In agricultural terms, the term 'poaching' is also applied to the loss of soils or grass sward by the damaging action of feet of livestock which can affect availability of productive land, water pollution through increased runoff and welfare issues for cattle.

Legal Aspects

Continental Europe

Austria and Germany refer to poaching not as theft, but as intrusion in third party hunting rights. While Germanic law allowed any free man including peasants to hunt, especially on the commons, roman law restricted hunting for the rulers. Medieval Europe saw feudal territory rulers from the king downward trying to enforce exclusive rights of the nobility to hunt and fish on the lands they ruled. Poaching was being deemed a serious crime punishable by imprisonment but the enforcement, till the 16th century, was comparably weak. Peasants still were able to continue small game hunting, the right of the nobility to hunt was restricted in the 16th century and transferred to land ownership.



Grave of famous poacher Georg Jennerwein in Schliersee. It quotes the first stanza of the Jennerwein song. Now and then, poached game is being placed on the grave to commemorate 'Girgl'.

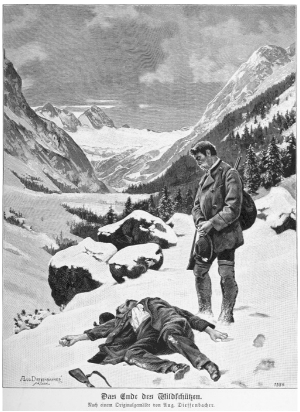
The development of modern hunting rights is closely connected to the comparably modern idea of exclusive private property of land. In the 17th and 18th centuries the restrictions on hunting and shooting rights on private property were being enforced by gamekeepers and foresters. They denied shared usages of forests, e.g. resin collection and wood pasture and the peasant's right to hunt and fish. However, comparably easy access to rifles increasingly allowed peasants and servants to poach end of the 18th century.

The low quality of guns made it necessary to approach to the game as close as 30 meters (33 yards). For example poachers in the Salzburg region then were around 30 years old men, not yet married and usually alone on their illegal trade. Hunting was being used in the 18th century as a theatrical demonstration of aristocratic rule of the land and had a strong impact on land use patterns as well. Poaching in so far inferred not only with property rights but clashed symbolically with the power of the nobility. The years between 1830 and 1848 saw a strong increase in poaching and poaching related deaths in Bavaria. The revolution of 1848 was interpreted as a general allowance for poaching in Bavaria. The reform of hunting law in 1849 reduced legal hunting to rich land owners and the bourgeoisie able to pay the hunting fees and led to disappointment and ongoing praise of poachers among the people . Some of the frontier region, where smuggling was of importance, showed especially strong resistance. In 1849, the Bavarian military forces were being asked to occupy a number of municipalities on the frontier to Austria. Both, in Wallgau (today a part of Garmisch-Partenkirchen) and in Lackenhäuser, (close to Wegscheid in the Bavarian forest) one soldier per household was to be fed and kept for a month as part of a military mission to quell the uproar. The people of Lackenhäuser had had several skirmishes about poached deer with Austrian foresters and even military and were known as well armed *pertly poachers* (kecke Wilderer).

United Kingdom

Poaching, like smuggling, has a long counter-cultural history. The verb *poach* is derived from the Middle English word *pocchen* literally meaning *bagged*, *enclosed in a bag*.

Lady Baltimore, a bald eagle in Alaska who survived a poaching attempt, in her Juneau Raptor Center mew, on 15 August 2015



End of the poacher, illustration based on a painting of August Dieffenbacher 1894.

Poaching was dispassionately reported for England in "Pleas of the Forest", transgressions of the rigid Anglo-Norman Forest Law. William the Conqueror, a great lover of hunting, had established and enforced a system of forest law. This operated outside the common law, and served to protect game animals and their forest habitat from destruction. 1087, a poem, "The Rime of King William" in the Peterborough Chronicle, expressed English indignation. Poaching was romanticized in literature from the time of the ballads of Robin Hood, as an aspect of the "greenwood" of Merry England. *Non est inquirendum, unde venit venison* ("It is not to be inquired, whence comes the venison"), observed Guillaume Budé in his *Traitte de la vénerie*. However, the English nobility and land owners were much more successful in enforcing the modern concept of property, expressed e.g. in the enclosures and later in the highland Clearances, both forced displacement of people from traditional land tenancies. The 19th century saw the rise of acts of legislation, such as the Night Poaching Act 1828 and Game Act 1831 in the United Kingdom, and various laws elsewhere.

Poaching in the USA

In North America, the blatant defiance of the laws by poachers escalated to armed conflicts with law authorities, including the Oyster Wars of the Chesapeake Bay, and the joint US-British Bering Sea Anti-Poaching Operations of 1891 over the hunting of seals.

Violations of hunting laws and regulations concerning wildlife management, local or international wildlife conservation schemes constitute wildlife crimes that are typically punishable. The following violations and offenses are considered acts of poaching in the USA:

- Hunting, killing or collecting wildlife that is listed as endangered by IUCN and protected by law such as the Endangered Species Act, the Migratory Bird Treaty Act of 1918 and international treaties such as CITES.
- Fishing and hunting without a license.
- Capturing wildlife outside legal hours and outside the hunting season; usually the breeding season is declared as the closed season during which wildlife is protected by law.
- Prohibited use of machine guns, poison, explosives, snare traps, nets and pitfall traps.
- Prohibited use of baiting with food, decoys or recorded calls in order to increase chances for shooting wildlife.
- Hunting from a moving vehicle or aircraft.
- Shining deer with a spotlight at night to impair its natural defenses and thus facilitate an easy kill is considered animal abuse. This hunting method is illegal in California, Virginia, Connecticut, Florida, Michigan and Tennessee.

- Taking wildlife on land that is restricted, owned by or licensed to somebody else.
- The animal or plant has been tagged by a researcher.

Environmental Law

In 1998 environmental scientists from the University of Massachusetts Amherst proposed the concept of poaching as an environmental crime, defining any activity as illegal that contravenes the laws and regulations established to protect renewable natural resources including the illegal harvest of wildlife with the intention of possessing, transporting, consuming or selling it and using its body parts. They considered poaching as one of the most serious threats to the survival of plant and animal populations. Wildlife biologists and conservationists consider poaching to have a detrimental effect on biodiversity both within and outside protected areas as wildlife populations decline, species are depleted locally, and the functionality of ecosystems is disturbed.

Stephen Corry, director of the human-rights group Survival International, has argued that the term "poaching" has at times been used to criminalize the traditional subsistence techniques of indigenous peoples and bar them from hunting on their ancestral lands, when these lands are declared wildlife-only zones. Corry argues that parks such as the Central Kalahari Game Reserve are managed for the benefit of foreign tourists and safari groups, at the expense of the livelihoods of tribal peoples such as the Kalahari Bushmen.

Motives

Sociological and criminological research on poaching indicates that in North America people poach for commercial gain, home consumption, trophies, pleasure and thrill in killing wildlife, or because they disagree with certain hunting regulations, claim a traditional right to hunt, or have negative dispositions toward legal authority. In rural areas of the United States, the key motives for poaching are poverty. Interviews conducted with 41 poachers in the Atchafalaya River basin in Louisiana revealed that 37 of them hunt to provide food for themselves and their families; 11 stated that poaching is part of their personal or cultural history; nine earn money from the sale of poached game to support their families; eight feel exhilarated and thrilled by outsmarting game wardens.

In African rural areas, the key motives for poaching are the lack of employment opportunities and a limited potential for agriculture and livestock production. Poor people rely on natural resources for their survival and generate cash income through the sale of bushmeat, which attracts high prices in urban centres. Body parts of wildlife are also in demand for traditional medicine and ceremonies. The existence of an international market for poached wildlife implies that well-organised gangs of professional poachers enter vulnerable areas to hunt, and crime syndicates organise the trafficking of wildlife body parts through a complex interlinking network to markets outside the respective countries of origin.

Effects of Poaching

Memorial to rhinos killed by poachers near St Lucia Estuary, South Africa

The detrimental effects of poaching can include:

- Defaunation of forests: predators, herbivores and fruit-eating vertebrates cannot recover as fast as they are removed from a forest; as their populations decline, the pattern of seed predation and dispersal is altered; tree species with large seeds progressively dominate a forest, while small-seeded plant species become locally extinct.
- Reduction of animal populations in the wild and possible extinction.
- The effective size of protected areas is reduced as poachers use the edges of these areas as open-access resources.
- Wildlife tourism destinations face a negative publicity; those holding a permit for wildlife-based land uses, tourism-based tour and lodging operators lose income; employment opportunities are reduced.
- Emergence of zoonotic diseases caused by transmission of highly variable retrovirus chains:
    - Outbreaks of the Ebola virus in the Congo Basin and in Gabon in the 1990s have been associated with the butchering of apes and consumption of their meat.
    - The outbreak of SARS in Hong Kong is attributed to contact with and consumption of meat from masked palm civets, raccoon dogs, Chinese ferret-badgers and other small carnivores that are available in southern Chinese wildlife markets.
    - Bushmeat hunters in Central Africa infected with the human T-lymphotropic virus were closely exposed to wild primates.

- Results of research on wild chimpanzees in Cameroon indicate that they are naturally infected with the simian foamy virus and constitute a reservoir of HIV-1, a precursor of the acquired immunodeficiency syndrome in humans.

Many tribal people in Africa, Brazil and India rely on hunting for food and have become victims of the fallout from poaching. In the Indian Kanha Tiger Reserve, they are prevented from hunting, and were illegally evicted from their lands following the creation of nature reserves aimed to protect animals. Tribal people are often falsely accused of contributing to the decline of wildlife. In India for example, they bear the brunt of anti-tiger poaching measures, despite the main reason for the tiger population crash in the 20th century being due to hunting by European colonists and Indian royalties. Stephen Corry, director of the human-rights group Survival International, argues that indigenous peoples have shaped landscapes and managed animal populations for millennia. He asserts that conservation organizations such as the World Wildlife Fund apply the term "poaching" unfairly to tribal people engaging in subsistence hunting while supporting trophy hunting by tourists for a fee.

Products

The body parts of many animals, such as tigers and rhinoceroses, are believed to have certain positive effects on the human body, including increasing virility and curing cancer. These parts are sold in areas where these beliefs are practiced – mostly Asian countries particularly Vietnam and China – on the black market.

A seashell vendor in Tanzania sells to tourists seashells which have been taken from the sea alive, killing the animal inside.

Traditional Chinese medicine often incorporates ingredients from all parts of plants, the leaf, stem, flower, root, and also ingredients from animals and minerals. The use of parts of endangered species (such as seahorses, rhinoceros horns, binturong and tiger bones and claws) has created controversy and resulted in a black market of poachers. Deep-seated cultural beliefs in the potency of tiger parts are so prevalent across China and other east Asian countries that laws protecting even critically endangered species such as the Sumatran tiger fail to stop the display and sale of these items in open markets, according to a 2008 report from TRAFFIC. Popular "medicinal" tiger parts from poached animals include tiger genitals, culturally believed to improve virility, and tiger eyes.

A vendor selling illegal items at a Chinese market for use in traditional Chinese medicine. Some of the pieces pictured include parts of animals such as a tiger's paw.

Rhino populations face extinction because of demand in Asia (for traditional medicine and as a luxury item) and in the Middle East (where horns are used for decoration). A sharp surge in demand for rhino horn in Vietnam was attributed to rumors that the horn cured cancer, even though the rumor has no basis in science. Recent prices for a kilo of crushed rhino horn have gone for as much as $60,000, more expensive than a kilo of gold. Vietnam is the only nation which mass-produces bowls made for grinding rhino horn.

Ivory, which is a natural material of several animals, plays a large part in the trade of illegal animal materials and poaching. Ivory is a material used in creating art objects and jewelry where the ivory is carved with designs. China is a consumer of the ivory trade and accounts for a significant amount of ivory sales. In 2012, *The New York Times* reported on a large upsurge in ivory poaching, with about 70% of all illegal ivory flowing to China.

Fur is also a natural material which is sought after by poachers. A Gamsbart, literally *chamois beard*, a tuft of hair traditionally worn as a decoration on trachten-hats in the alpine regions of Austria and Bavaria formerly was worn as a hunting (and poaching) trophy. In the past, it was made exclusively from hair from the chamois' lower neck.

Anti-poaching Efforts

Africa

Members of the *Rhino Rescue Project* have implemented a technique to combat rhino poaching in South Africa by injecting a mixture of indelible dye and a parasiticide, which enables tracking of the horns and deters consumption of the horn by purchasers. Since rhino horn is made of keratin, advocates say the procedure is painless for the animal.

Another initiative that seeks to protect Africa's elephant populations from poaching activities is the Tanzanian organization Africa's Wildlife Trust. Hunting for ivory was banned in 1989, but poaching of elephants continues in many parts of Africa stricken by economic decline.

Brass Plaque on door at Tremeddafarm, Zennor, Cornwall, England. It reads: *Take notice that as from today's date poachers shall be shot on first sight and if practicable questioned afterwards. By order: J.R. Bramble, Head Gamekeeper to His Grace the Duke of Gumby. 1st November 1868*

The International Anti-Poaching Foundation has a structured military-like approach to conservation, employing tactics and technology generally reserved for the battlefield. Founder Damien Mander is an advocate of the use of military equipment and tactics, including Unmanned Aerial Vehicles, for military-style anti-poaching operations. Such military-style approaches have garnered some criticism. Rosaleen Duffy of the University of London writes that military approaches to conservation fail to resolve the underlying reasons leading to poaching, and do not tackle either "the role of global trading networks" or continued demand for illegal animal products. According to Duffy, such methods "result in coercive, unjust and counterproductive approaches to wildlife conservation".

Chengeta Wildlife is an organization that works to equip and train wildlife protection teams and lobbies African governments to adopt anti-poaching campaigns.

Jim Nyamu's elephant walks are part of attempts in Kenya to reduce ivory poaching.

Asia

Large quantities of ivory are sometimes destroyed as a statement against poaching (aka "ivory crush"). In 2013 the Philippines were the first country to destroy their national seized ivory stock. In 2014 China followed suit and crushed six tons of ivory as a symbolic statement against poaching.

United States of America

Some game wardens have made use of robotic decoy animals placed in high visibility areas to draw out poachers for arrest after the decoys are shot and decoys with robotics to mimic natural movements are also in use by law enforcement.

Sturgeon and paddlefish (aka “spoonbill catfish”) are listed as species of “special concern” by the U.S. Federal government, but are only banned from fishing in a few states such as Mississippi and Texas.

Marterl at the Riederstein. close to Baumgartenschneid, Tegernsee. The remnants of a poacher, which didn’t return from a hunt in 1861 have been found at the place in 1897.

Europe

Some poachers and their violent ends, as Matthias Klostermayr (1736-1771), Georg Jennerwein (1848-1877) and Pius Walder (1952 -1982) gained notoriety and had a strong cultural impact till the present. Poaching was being used then as a dare. It had a certain erotic connotation, as e.g. in Franz Schubert’s Hunter’s love song, (1828, D 909). The lyrics of Franz von Schobers connected unlimited hunting with the pursuit of love. Further poaching related legends and stories include the 1821 opera Freischütz till Wolfgang Franz von Kobell’s 1871 story about the Brandner Kasper, a Tegernsee locksmith and poacher achieving a special deal with the grim reaper .

While poachers had strong local support until the early 20th century, Walder’s case showed a significant change in attitudes. Urban citizens still had some sympathy for the hillbilly rebel, while the local community were much less in favor.

Human–wildlife Conflict

Human–wildlife conflict refers to the interaction between wild animals and people and the resultant negative impact on people or their resources, or wild animals or their habitat. It occurs when growing human populations overlap with established wildlife territory, creating reduction of resources or life to some people and/or wild animals. The conflict takes many forms ranging from loss of life or injury to humans, and animals both wild and domesticated, to competition for scarce resources to loss and degradation of habitat.

Grand Canyon National Park hosts millions of visitors every year and is home to a population of Rocky Mountain elk. Interactions between humans and the elk sometimes results in injuries.

Conflict management strategies earlier comprised lethal control, translocation, regulation of population size and preservation of endangered species. Recent management approaches attempt to use scientific research for better management outcomes, such as behaviour modification and reducing interaction. As human-wildlife conflicts inflict direct, indirect and opportunity costs, the mitigation of human-wildlife conflict is an important issue in the management of biodiversity and protected areas.

Definition

Human–wildlife conflict is defined by the World Wide Fund for Nature (WWF) as "any interaction between humans and wildlife that results in negative impacts on human social, economic or cultural life, on the conservation of wildlife populations, or on the environment.Fund for Nature Southern African Regional Programme Office . The *Creating Co-existence* workshop at the 5th Annual World Parks Congress (8–17 September 2003, Montreal) defined human-wildlife conflict in the context of human goals and animal needs as follows: "Human-wildlife conflict occurs when the needs and behavior of wildlife impact negatively on the goals of humans or when the goals of humans negatively impact the needs of wildlife."

A 2007 review by the United States Geological Survey defines human-wildlife conflict in two contexts; firstly, actions by wildlife conflict with human goals, i.e. life, livelihood and life-style, and, secondly, human activities threaten the safety and survival of wildlife. However, in both cases, outcomes are decided by human responses to the interactions.

The Government of Yukon defines human-wildlife conflict simply, but through the lens of damage to property, i.e. "any interaction between wildlife and humans which causes harm, whether it's to the human, the wild animal, or property." Here, property includes buildings, equipment and camps, livestock and pets, but does not include crops, fields or fences. WAP

History

Human–wildlife conflicts have occurred throughout man's prehistory and recorded history. Amongst the early forms of human-wildlife conflict is the predation of the ancestors of prehistoric man by a number of predators of the Miocene such as saber-toothed cats, leopards, spotted hyenas amongst others.

Fossil remains of early hominids show evidence of predation; the Taung Child, the fossilised skull of a young *Australopithecus africanus*, is thought to have been killed by an eagle from the distinct marks on its skull and the fossil having been found amongst egg shells and remains of small animals.

A Plio-Pleistocene horned crocodile, *Crocodylus anthropophagus*, whose fossil remains have been recorded from Olduvai Gorge, was the largest predator encountered by prehistoric man, as indicated by hominid specimens preserving crocodile bite marks from these sites.

The advent of farming and animal husbandry of the Neolithic Revolution increased the scope of conflict between humans and animals. The crops and the produce formed an abundant and easily obtained food source for wild animals. Wild herbivores competed with domesticated ones for pasture. In addition, they were a source for diseases which affected livestock. The livestock attracted predators which found them an easy source to prey on. The inevitable human reaction was to eliminate such threats to agriculture and domesticated animals. In addition, land was converted to agricultural and other uses and forests cleared, all of which impacted wild animals adversely. A number of animal species were eliminated locally or from parts of their natural range. The deliberate or accidental introduction of animals in isolated island animal communities have caused extinction of a large number of species.

Nature of Human-wildlife Conflicts

Causes

As human populations expand into wild animal habitats, natural wildlife territory is displaced. Reduction in the availability of natural prey/food sources leads to wild animals seeking alternate sources. Alternately, new resources created by humans draw wildlife resulting in conflict. The population density of wildlife and humans increase with overlaps in geographical areas used increasing their interaction thus resulting in increased physical conflict. Byproducts of human existence offer un-natural opportunity for wildlife in the form of food and sheltered interference and potentially destructive threat for both man and animals. Competition for food resources also occurs when humans attempt to harvest natural resources such as fish and grassland pasture.

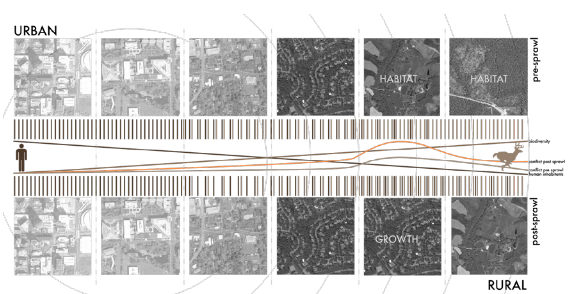


Diagram of Human Wildlife Conflict in Expanding American Cities

Outcomes of Conflict

Human–wildlife conflict occurs with various negative results. The major outcomes of human-wildlife conflict are:

- Injury and loss of life of humans and wildlife.
- Crop damage, livestock depredation, predation of managed wildlife stock.
- Damage to human property.
- Trophic cascades.
- Destruction of habitat.
- Collapse of wildlife populations and reduction of geographic ranges.

One of the initiators of the concept of man-animal conflict was Das and Guha. They described the two-sided impacts of this conflict. From one side, the source of conflict is the restriction on the local people to access forest resources. On the other side, the source of conflict is the damage incurred to them by wild animals.

Hidden Dimensions of Conflict

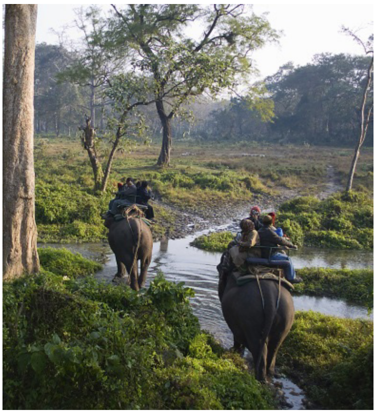
Human wildlife conflict also has a range of 'hidden' dimensions that are not typically factored in when the focus is on visible impacts. These can include health impacts, opportunity and transaction costs. Case studies include work on elephants in northeast India, where elephant-man interactions are seen to lead to cases of increased imbibing of alcohol by crop guardians with resultant enhanced mortality in encounters., and issues related to gender in northern India.

Conflict Resolution or Management

The aim of conflict resolution or management is to reduce the potential for human-wildlife conflicts in order to protect life and limb, safety and security of animal populations, habitat and general biodiversity, and also to minimise damage to property. The preference is always for passive, non-intrusive prevention measures but often active intervention is required to be carried out in conjunction.

Management Techniques

Management techniques of wildlife are of two types. The first type are the traditional techniques which aim to stop, reduce or minimise conflict by controlling animal populations in different ways. Lethal control has the longest history but has major drawbacks. Other measures, less costly in terms of life, are trans-location, regulation and preservation of animal populations. Modern methods depend upon the understanding of ecological and ethological understanding of the wildlife and its environment to prevent or minimise conflict; examples being behavioural modification and measures to reduce interaction between humans and wildlife.



Ecotourism by elephant safari through the Jaldapara Wildlife Sanctuary in West Bengal, India

Potential solutions to these conflicts include electric fencing, land use planning, community-based natural resource management (CBNRM), compensation, payment for environmental services, ecotourism, wildlife friendly products, or other field solutions.

In efforts to reduce human-wildlife conflict, World Wide Fund for Nature (WWF) has partnered with a number of organizations to provide solutions around the globe. Their solutions are tailored to the community and species involved. For example, in Mozambique, communities started to grow more chili pepper plants after making the discovery that elephants dislike and avoid plants containing capsaicin. This creative and effective method prevents elephants from trampling community farmers' fields as well as protects the species.

Human–lion Conflict

Signage in Addo Elephant National Park reminding humans of their position in the food chain.

Human–lion conflict refers to the pattern of problematic interactions between native people and lions. Conflict with humans is a major contributor of the decline in lion populations in Africa. Habitat loss and fragmentation due to conversion of land for agriculture has forced lions to live in closer proximity to human settlements. As a result, conflict is often characterized by lions preying upon livestock, known as livestock depredation. When depredation events take place, farmers suffer financial losses and lions face threats of retaliatory killing.

Causes of Conflict

The main cause of conflict is habitat loss. 83% of the African lion's range has been reduced and what remains is increasingly fragmented. Lions, as large carnivores, rely on large connected expanses of land. The conversion of their habitat into agricultural land prevents them from dispersing and can limit the availability of natural prey. Lions are therefore roaming closer to farms than before and are at a higher risk of preying on livestock.

Ecological Variables

There are many ecological variables that can affect likelihood of depredation. Factors such as farms' distance from water sources, protected areas, elevation and surrounding vegetative cover may all play a role. Some research has shown that depredation decreases with distance from protected areas. This could be because access to nearby conservation areas provides lions with a refuge when coming into contact with humans. Farms that are located close to water sources and at a low elevation may be especially vulnerable to conflict. The effect of vegetative cover remains unclear. Dense vegetative cover has been associated with a higher rate of depredation yet has also been shown to reduce depredation as it allows predators to hide from humans. Farm and livestock management can also affect chances of depredation. Corralling livestock at night as well as providing guards to monitor lion movements to prevent and deter predation can limit losses.

Financial Losses

Depredation events lead to financial losses to farmers who rely on livestock as a source of income. In the North West province of South Africa, around $375, 797USD were lost as a result of game and livestock losses caused by depredation. It should be noted that lions are not the only predators involved, with hyenas, leopards, and wild dogs responsible for depredation events as well. However, lions typically attack cattle which incur higher financial losses than sheep and goats (hunted by hyenas and leopards).

Compensation

In order to lessen these financial losses, some regions offer financial compensation to affected farmers. However, these programs are not always effective. Major criticisms revolve around the response times of programs, arguing that they take too long or do not happen at all. Additionally, farmers do not always receive sufficient financial restitution. For example, as of 2009, Botswana's state-funded compensation program only compensated farmers for 80% of the value they lost. It is common for farmers to not even report livestock losses due in part to dissatisfaction with response time and amount. However, the Predator Compensation Fund (PCF) in Massailand, Kenya has reduced retaliatory killings following depredation events by 73%, illustrating that when done correctly, compensation programs can be effective. Farmers who have received compensation have also reported a lower likelihood of killing a suspected lion than those who have not received any. Regardless of their efficacy, compensation programs are reactionary and not preventative, only seeking to mitigate farmers' losses after the event and do not address underlying causes of conflict

Retaliatory Killing

Retaliatory killing is the hunting of a suspected predator after a depredation event. While a threat for all predators, lions are killed disproportionately to the number of losses they are responsible for as opposed to hyenas and leopards. One reason lions are killed in retaliation more than other carnivores is because of their propensity to kill cattle more than sheep and goats. Because cattle are of more financial value to farmers than sheep and goats, the desire to retaliate can be greater. Lions also will hunt during the night when most attacks take place, are easier to track, and are more likely to defend a carcass which make them more vulnerable to being killed by humans

Likelihood of Retaliation

Social and economic differences also impact motivation to hunt lions in reaction to livestock losses. People who have lost a higher proportion of their livestock to depredation (often those with smaller farms to begin with) as well as those owning livestock for the purpose of sale as opposed to traditional or subsistence reasons have been found to report a higher willingness to retaliate. Both higher proportional losses and keeping livestock for sale increase the value of cattle and therefore increase the financial incentive to kill suspected predators. Likelihood to retaliate has also been shown to be influenced by social factors such as religion and culture

Reducing Conflict

Due to the complex social, economic, and ecological aspects of human-lion conflict, it is recommended that mitigation strategies be adaptable and situation-specific. Specific actions such as providing guards to monitor predators and protect cattle, corralling livestock at night, providing compensation and restoring natural prey densities may reduce conflict in some areas. Focusing on unique conservation programs that take into account factors such as culture and religion, type of livestock owned, and reason for owning livestock may also be helpful.

Disturbance (Ecology)

In biology, a disturbance is a temporary change in environmental conditions that causes a pronounced change in an ecosystem. Disturbances often act quickly and with great effect, to alter the physical structure or arrangement of biotic and abiotic elements. Major ecological disturbances may include fires, flooding, windstorms, insect outbreaks and trampling. Earthquakes, various types of volcanic eruptions, tsunami, firestorms, impact events, climate change, and the devastating effects of human impact on the environment (anthropogenic disturbances) such as clearcutting, forest clearing and the introduction of invasive species can be considered major disturbances. Disturbance forces can have profound immediate effects on ecosystems and can, accordingly, greatly alter the natural community. Because of these and the impacts on populations, these effects can continue for an extended period of time.

Damages of storm Kyrill in Wittgenstein, Germany.

Criteria

Conditions under which natural disturbances occur are influenced mainly by climate, weather, and location. Fire disturbances will only occur in areas where there is low precipitation, some form of ignition (typically lightning), and enough flammable biomass to allow fire to spread. Conditions often occur as part of a cycle and disturbances may be periodic. Other disturbances, such as those caused by humans, invasive species or impact events, can occur anywhere and are not necessarily cyclic. Extinction vortices may result in multiple disturbances or a greater frequency of a single disturbance.

Cyclic Disturbance

Often, when disturbances occur naturally, they provide conditions that favor the success of different species over pre-disturbance organisms. This can be attributed to physical changes in the biotic and abiotic conditions of an ecosystem. Because of this, a disturbance force can change an ecosystem for significantly longer than the period over which the immediate effects persist. However, in the absence of further disturbance forces, many ecosystems will trend back toward pre-disturbance conditions. Such alteration, accompanied by changes in the abundance of different species over time, is called ecological succession. Succession often leads to conditions that will once again predispose an ecosystem to disturbance.

Pine forests in the western North America provide a good example of such a cycle involving insect outbreaks. The mountain pine beetle (*Dendroctonus ponderosae*) play an important role in limiting pine trees like lodgepole pine in forests of western North America. In 2004 the beetles affected more than 90,000 square kilometres. The beetles exist in endemic and epidemic phases. During epidemic phases swarms of beetles kill large numbers of old pines. This mortality creates openings in the forest for new vegetation. Spruce, fir, and younger pines, which are unaffected by the beetles, thrive in canopy openings. Eventually pines grow into the canopy and replace those lost. Younger pines are often able to ward off beetle attacks but, as they grow older, pines become less vigorous and more susceptible to infestation. This cycle of death and re-growth creates a temporal mosaic of pines in the forest. Similar cycles occur in association with other disturbances such as fire and windthrow.

Compound Disturbances

When multiple disturbance events affect the same location in quick succession, this often results in a “compound disturbance,” an event which, due to the combination of forces, creates a new situation which is more than the sum of its parts. For example, windstorms followed by fire can create fire temperatures and durations that are not expected in even severe wildfires, and may have surprising effects on post-fire succession.

Species Adapted to Disturbance

Forest fire burns on the island of Zakynthos in Greece on July 25th, 2007.

A disturbance may change a forests significantly. Afterwards, the forest floor is often littered with dead material. This decaying matter and abundant sunlight promote an abundance of new growth. In the case of forest fires a portion of the nutrients previously held in plant biomass is returned quickly to the soil as biomass burns. Many plants and animals benefit from disturbance conditions. Some species are particularly suited for exploiting recently disturbed sites. Vegetation with the potential for rapid growth can quickly take advantage of the lack of competition. In the northeastern United States, shade-intolerant trees like pin cherry and aspen quickly fill in forest gaps created by fire or windthrow (or human disturbance). Silver maple and eastern sycamore are similarly well adapted to floodplains. They are highly tolerant of standing water and will frequently dominate floodplains where other species are periodically wiped out.

Another species which is well adapted to a particular disturbance is the Jack Pine in boreal forests exposed to crown fires. They, as well as some other pine species, have specialized serotinous cones that only open and disperse seeds with sufficient heat generated by fire. As a result, this species often dominates in areas where competition has been reduced by fire.

Species that are well adapted for exploiting disturbance sites are referred to as pioneers or early successional species. These shade-intolerant species are able to photosynthesize at high rates and as a result grow quickly. Their fast growth is usually balanced by short life spans. Furthermore, although these species often dominate immediately following a disturbance, they are unable to compete with shade-tolerant species later on and replaced by these species through succession.

While plants must deal directly with disturbances, many animals are not as immediately affected by them. Most can successfully evade fires, and many thrive afterwards on abundant new growth on the forest floor. New conditions support a wider variety of plants, often rich in nutrients compared to pre-disturbance vegetation. The plants in turn support a variety of wildlife, temporarily increasing biological diversity in the forest.

Importance

Biological diversity is dependent on natural disturbance. The success of a wide range of species from all taxonomic groups is closely tied to natural disturbance events such as fire, flooding, and windstorm. As an example, many shade-intolerant plant species rely on disturbances for successful establishment and to limit competition. Without this perpetual thinning, diversity of forest flora can decline, affecting animals dependent on those plants as well.

A good example of this role of disturbance is in ponderosa pine (*Pinus ponderosa*) forests in the western United States, where surface fires frequently thin existing vegetation allowing for new growth. If fire is suppressed, douglas fir (*Pesudotsuga menziesii*), a shade tolerant species, eventually replaces the pines. Douglas firs, having dense crowns, severely limit the amount of sunlight reaching the forest floor. Without sufficient light new growth is severely limited. As the diversity of surface plants decreases, animal species that rely on them diminish as well. Fire, in this case, is important not only to the species directly affected but also to many other organisms whose survival depends on those key plants.

Habitat Destruction

Habitat destruction is the process in which natural habitat is rendered unable to support the species present. In this process, the organisms that previously used the site are displaced or destroyed, reducing biodiversity. Habitat destruction by human activity is mainly for the purpose of harvesting natural resources for industry production and urbanization. Clearing habitats for agriculture is the principal cause of habitat destruction. Other important causes of habitat destruction include mining, logging, trawling and urban sprawl. Habitat destruction is currently ranked as the primary cause of species extinction worldwide. It is a process of natural environmental change that may be caused by habitat fragmentation, geological processes, climate change or by human activities such as the introduction of invasive species, ecosystem nutrient depletion, and other human activities

The terms habitat loss and habitat reduction are also used in a wider sense, including loss of habitat from other factors, such as water and noise pollution.

Impacts on Organisms

In the simplest term, when a habitat is destroyed, the plants, animals, and other organisms that occupied the habitat have a reduced carrying capacity so that populations decline and extinction becomes more likely. Perhaps the greatest threat to organisms and biodiversity is the process of habitat loss. Temple (1986) found that 82% of endangered bird species were significantly threatened by habitat loss. Endemic organisms with limited ranges are most affected by habitat destruction, mainly because these organisms are not found anywhere else within the world and thus, have less chance of recovering. Many endemic organisms have very specific requirements for their survival that can only be found within a certain ecosystem, resulting in their extinction. Extinction may also take place very long after the destruction of habitat, a phenomenon known as extinction debt. Habitat destruction can also decrease the range of certain organism populations. This can result in the reduction of genetic diversity and perhaps the production of infertile youths, as these organisms would have a higher possibility of mating with related organisms within their population, or different species. One of the most famous examples is the impact upon China's giant panda, once found across the nation. Now it is only found in fragmented and isolated regions in the southwest of the country, as a result of widespread deforestation in the 20th century.

Geography

Biodiversity hotspots are chiefly tropical regions that feature high concentrations of endemic species and, when all hotspots are combined, may contain over half of the world's terrestrial species. These hotspots are suffering from habitat loss and destruction. Most of the natural habitat on islands and in areas of high human population density has already been destroyed (WRI, 2003). Islands suffering extreme habitat destruction include New Zealand, Madagascar, the Philippines, and Japan. South and east Asia — especially China, India, Malaysia, Indonesia, and Japan — and many areas in West Africa have extremely dense human populations that allow little room for natural habitat. Marine areas close to highly populated coastal cities also face degradation of their coral reefs or other marine habitat. These areas include the eastern coasts of Asia and Africa, northern coasts of South America, and the Caribbean Sea and its associated islands.

Satellite photograph of deforestation in Bolivia. Originally dry tropical forest, the land is being cleared for soybean cultivation.

Regions of unsustainable agriculture or unstable governments, which may go hand-in-hand, typically experience high rates of habitat destruction. Central America, Sub-Saharan Africa, and the Amazonian tropical rainforest areas of South America are the main regions with unsustainable agricultural practices or government mismanagement.

Areas of high agricultural output tend to have the highest extent of habitat destruction. In the U.S., less than 25% of native vegetation remains in many parts of the East and Midwest. Only 15% of land area remains unmodified by human activities in all of Europe.

Ecosystems

Tropical rainforests have received most of the attention concerning the destruction of habitat. From the approximately 16 million square kilometers of tropical rainforest habitat that originally existed worldwide, less than 9 million square kilometers remain today. The current rate of deforestation is 160,000 square kilometers per year, which equates to a loss of approximately 1% of original forest habitat each year.

Jungle burned for agriculture in southern Mexico

Other forest ecosystems have suffered as much or more destruction as tropical rainforests. Farming and logging have severely disturbed at least 94% of temperate broadleaf forests; many old growth forest stands have lost more than 98% of their previous area because of human activities. Tropical deciduous dry forests are easier to clear and burn and are more suitable for agriculture and cattle ranching than tropical rainforests; consequently, less than 0.1% of dry forests in Central America's Pacific Coast and less than 8% in Madagascar remain from their original extents.

Farmers near newly cleared land within Taman Nasional Kerinci Seblat (Kerinci Seblat National Park), Sumatra.

Plains and desert areas have been degraded to a lesser extent. Only 10-20% of the world's drylands, which include temperate grasslands, savannas, and shrublands, scrub, and deciduous forests, have been somewhat degraded. But included in that 10-20% of land is the approximately 9 million square kilometers of seasonally dry-lands that humans have converted to deserts through the process of desertification. The tallgrass prairies of North America, on the other hand, have less than 3% of natural habitat remaining that has not been converted to farmland.

Wetlands and marine areas have endured high levels of habitat destruction. More than 50% of wetlands in the U.S. have been destroyed in just the last 200 years. Between 60% and 70% of European wetlands have been completely destroyed. About one-fifth (20%) of marine coastal areas have been highly modified by humans. One-fifth of coral reefs have also been destroyed, and another fifth has been severely degraded by overfishing, pollution, and invasive species; 90% of the Philippines' coral reefs alone have been destroyed. Finally, over 35% mangrove ecosystems worldwide have been destroyed.

Natural Causes

Habitat destruction through natural processes such as volcanism, fire, and climate change is well documented in the fossil record. One study shows that habitat fragmentation of tropical rainforests in Euramerica 300 million years ago led to a great loss of amphibian diversity, but simultaneously the drier climate spurred on a burst of diversity among reptiles.

Human Causes

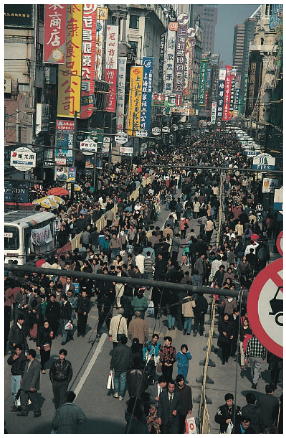
Habitat destruction caused by humans includes land conversion from forests, etc. to arable land, urban sprawl, infrastructure development, and other anthropogenic changes to the characteristics of land. Habitat degradation, fragmentation, and pollution are aspects of habitat destruction caused by humans that do not necessarily involve over destruction of habitat, yet result in habitat collapse. Desertification, deforestation, and coral reef degradation are specific types of habitat destruction for those areas (deserts, forests, coral reefs).

Deforestation and roads in Amazonia, the Amazon Rainforest.

Geist and Lambin (2002) assessed 152 case studies of net losses of tropical forest cover to determine any patterns in the proximate and underlying causes of tropical deforestation. Their results, yielded as percentages of the case studies in which each parameter was a significant factor, provide a quantitative prioritization of which proximate and underlying causes were the most significant. The proximate causes were clustered into broad categories of agricultural expansion (96%), infrastructure expansion (72%), and wood extraction (67%). Therefore, according to this study, forest conversion to agriculture is the main land use change responsible for tropical deforestation. The specific categories reveal further insight into the specific causes of tropical deforestation: transport extension (64%), commercial wood extraction (52%), permanent cultivation (48%), cattle ranching (46%), shifting (slash and burn) cultivation (41%), subsistence agriculture (40%), and fuel wood extraction for domestic use (28%). One result is that shifting cultivation is not the primary cause of deforestation in all world regions, while transport extension (including the construction of new roads) is the largest single proximate factor responsible for deforestation.

Drivers

While the above-mentioned activities are the proximal or direct causes of habitat destruction in that they actually destroy habitat, this still does not identify why humans destroy habitat. The forces that cause humans to destroy habitat are known as *drivers* of habitat destruction. Demographic, economic, sociopolitical, scientific and technological, and cultural drivers all contribute to habitat destruction.



Nanjing Road in Shanghai

Demographic drivers include the expanding human population; rate of population increase over time; spatial distribution of people in a given area (urban versus rural), ecosystem type, and country; and the combined effects of poverty, age, family planning, gender, and education status of people in certain areas. Most of the exponential human population growth worldwide is occurring in or close to biodiversity hotspots. This may explain why human population density accounts for 87.9% of the variation in numbers of threatened species across 114 countries, providing indisputable evidence that people play the largest role in decreasing biodiversity. The boom in human population and migration of people into such species-rich regions are making conservation efforts not only more urgent but also more likely to conflict with local human interests. The high local population density in such areas is directly correlated to the poverty status of the local people, most of whom lacking an education and family planning.

From the Geist and Lambin (2002) study described in the previous section, the underlying driving forces were prioritized as follows (with the percent of the 152 cases the factor played a significant role in): economic factors (81%), institutional or policy factors (78%), technological factors (70%), cultural or socio-political factors (66%), and demographic factors (61%). The main economic factors included commercialization and growth of timber markets (68%), which are driven by national and international demands; urban industrial growth (38%); low domestic costs for land, labor, fuel, and timber (32%); and increases in product prices mainly for cash crops (25%). Institutional and policy factors included formal pro-deforestation policies on land development (40%), economic growth including colonization and infrastructure improvement (34%), and subsidies for land-based activities (26%); property rights and land-tenure insecurity (44%); and policy failures such as corruption, lawlessness, or mismanagement (42%). The main technological factor was the poor application of technology in the wood industry (45%), which leads to wasteful logging practices. Within the broad category of cultural and sociopolitical factors are public attitudes and values (63%), individual/household behavior (53%), public unconcern toward forest environments (43%), missing basic values (36%), and unconcern by individuals (32%). Demographic factors were the in-migration of colonizing settlers into sparsely populated forest areas (38%) and growing population density — a result of the first factor — in those areas (25%).

There are also feedbacks and interactions among the proximate and underlying causes of deforestation that can amplify the process. Road construction has the largest feedback effect, because it interacts with—and leads to—the establishment of new settlements and more people, which causes a growth in wood (logging) and food markets. Growth in these markets, in turn, progresses the commercialization of agriculture and logging industries. When these industries become commercialized, they must become more efficient by utilizing larger or more modern machinery that often are worse on the habitat than traditional farming and logging methods. Either way, more land is cleared more rapidly for commercial markets. This common feedback example manifests just how closely related the proximate and underlying causes are to each other.

Impact on Human Population

Habitat destruction vastly increases an area's vulnerability to natural disasters like flood and drought, crop failure, spread of disease, and water contamination. On the other hand, a healthy ecosystem with good management practices will reduce the chance of these events happening, or will at least mitigate adverse impacts.

The draining and development of coastal wetlands that previously protected the Gulf Coast contributed to severe flooding in New Orleans, Louisiana in the aftermath of Hurricane Katrina.

Agricultural land can actually suffer from the destruction of the surrounding landscape. Over the past 50 years, the destruction of habitat surrounding agricultural land has degraded approximately 40% of agricultural land worldwide via erosion, salinization, compaction, nutrient depletion, pollution, and urbanization. Humans also lose direct uses of natural habitat when habitat is destroyed. Aesthetic uses such as birdwatching, recreational uses like hunting and fishing, and ecotourism usually rely upon virtually undisturbed habitat. Many people value the complexity of the natural world and are disturbed by the loss of natural habitats and animal or plant species worldwide.

Probably the most profound impact that habitat destruction has on people is the loss of many valuable ecosystem services. Habitat destruction has altered nitrogen, phosphorus, sulfur, and carbon cycles, which has increased the frequency and severity of acid rain, algal blooms, and fish kills in rivers and oceans and contributed tremendously to global climate change. One ecosystem service whose significance is becoming more realized is climate regulation. On a local scale, trees provide windbreaks and shade; on a regional scale, plant transpiration recycles rainwater and maintains constant annual rainfall; on a global scale, plants (especially trees from tropical rainforests) from around the world counter the accumulation of greenhouse gases in the atmosphere by sequestering carbon dioxide through photosynthesis. Other ecosystem services that are diminished or lost altogether as a result of habitat destruction include watershed management, nitrogen fixation, oxygen production, pollination, waste treatment (i.e., the breaking down and immobilization of toxic pollutants), and nutrient recycling of sewage or agricultural runoff.

The loss of trees from the tropical rainforests alone represents a substantial diminishing of the earth's ability to produce oxygen and use up carbon dioxide. These services are becoming even more important as increasing carbon dioxide levels is one of the main contributors to global climate change.

The loss of biodiversity may not directly affect humans, but the indirect effects of losing many species as well as the diversity of ecosystems in general are enormous. When biodiversity is lost, the environment loses many species that provide valuable and unique roles to the ecosystem. The environment and all its inhabitants rely on biodiversity to recover from extreme environmental conditions. When too much biodiversity is lost, a catastrophic event such as an earthquake, flood, or volcanic eruption could cause an ecosystem to crash, and humans would obviously suffer from that. Loss of biodiversity also means that humans are losing animals that could have served as biological control agents and plants that could potentially provide higher-yielding crop varieties, pharmaceutical drugs to cure existing or future diseases or cancer, and new resistant crop varieties for agricultural species susceptible to pesticide-resistant insects or virulent strains of fungi, viruses, and bacteria.

The negative effects of habitat destruction usually impact rural populations more directly than urban populations. Across the globe, poor people suffer the most when natural habitat is destroyed, because less natural habitat means less natural resources per capita, yet wealthier people and countries simply have to pay more to continue to receive more than their per capita share of natural resources.

Another way to view the negative effects of habitat destruction is to look at the opportunity cost of keeping an area undisturbed. In other words, what are people losing out on by taking away a given habitat? A country may increase its food supply by converting forest land to row-crop agriculture, but the value of the same land may be much larger when it can supply natural resources or services such as clean water, timber, ecotourism, or flood regulation and drought control.

Outlook

The rapid expansion of the global human population is increasing the world's food requirement substantially. Simple logic instructs that more people will require more food. In fact, as the world's population increases dramatically, agricultural output will need to increase by at least 50%, over the next 30 years. In the past, continually moving to new land and soils provided a boost in food production to appease the global food demand. That easy fix will no longer be available, however, as more than 98% of all land suitable for agriculture is already in use or degraded beyond repair.

The impending global food crisis will be a major source of habitat destruction. Commercial farmers are going to become desperate to produce more food from the same amount of land, so they will use more fertilizers and less concern for the environment to meet the market demand. Others will seek out new land or will convert other land-uses to agriculture. Agricultural intensification will become widespread at the cost of the environment and its inhabitants. Species will be pushed out of their habitat either directly by habitat destruction or indirectly by fragmentation, degradation, or pollution. Any efforts to protect the world's remaining natural habitat and biodiversity will compete directly with humans' growing demand for natural resources, especially new agricultural lands.

Solutions

In most cases of tropical deforestation, three to four underlying causes are driving two to three proximate causes. This means that a universal policy for controlling tropical deforestation would not be able to address the unique combination of proximate and underlying causes of deforestation in each country. Before any local, national, or international deforestation policies are written and enforced, governmental leaders must acquire a detailed understanding of the complex combination of proximate causes and underlying driving forces of deforestation in a given area or country. This concept, along with many other results about tropical deforestation from the Geist and Lambin study, can easily be applied to habitat destruction in general. Governmental leaders need to take action by addressing the underlying driving forces, rather than merely regulating the proximate causes. In a broader sense, governmental bodies at a local, national, and international scale need to emphasize the following:

Chelonia mydas on a Hawaiian coral reef. Although the endangered species is protected, habitat loss from human development is a major reason for the loss of green turtle nesting beaches.

1. Considering the many irreplaceable ecosystem services provided by natural habitats.
2. Protecting remaining intact sections of natural habitat.
3. Educating the public about the importance of natural habitat and biodiversity.
4. Developing family planning programs in areas of rapid population growth.
5. Finding ecological ways to increase agricultural output without increasing the total land in production.
6. Preserving habitat corridors to minimize prior damage from fragmented habitats.
7. Reduce human population and expansion.

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Diverse Approaches for Wildlife Conservation

The process of recreating a breed of species that has become extinct is known as de-extinction. Captive breeding is the process of breeding animals in an environment that is monitored by humans, such as wildlife and zoos. This chapter has been carefully written to provide an easy understanding of the diverse approaches to wildlife conservation.

De-extinction

De-extinction, or resurrection biology, or species revivalism is the process of creating an organism, which is either a member of, or resembles an extinct species, or breeding population of such organisms. Cloning is the most widely proposed method, although selective breeding has also been proposed. Similar techniques have been applied to endangered species.

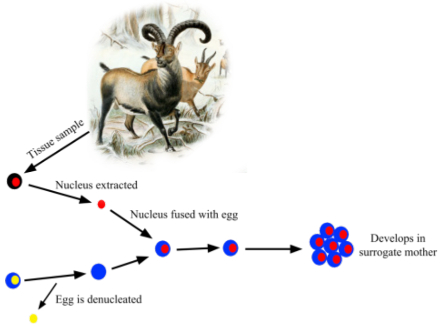
The Pyrenean ibex, or bucardo, is the first animal to have survived de-extinction past birth.

There is significant controversy over de-extinction. Critics assert that efforts would be better spent conserving existing species, and that the habitat necessary for formerly extinct species to survive is too limited to warrant de-extinction.

Methods

Cloning

Cloning is one method discussed as an option for bringing extinct species back. Proponents include author Stewart Brand, and proposed species include the passenger pigeon and the woolly mammoth. De-extinction efforts are now underway to revive the passenger pigeon by extracting DNA fragments and taking skin samples from preserved specimens and, later, using band-tailed pigeons or rock pigeons as surrogate parents.



Pictured above is the process used to clone the Pyrenean ibex in 2003. The tissue culture was taken from the last living, female Pyrenean ibex named Celia. The egg was taken from a goat (*Capra hircus*) and the nuclei removed to ensure the offspring was purely Pyrenean ibex. The egg was implanted into a surrogate goat mother for development.

A team of Russian and South Korean scientists are, as of April 2013, in the planning stages of cloning a woolly mammoth using an Asian elephant as a surrogate mother. Large amounts of well-preserved mammoth tissue have been found in Siberia. If the process can be completed, there are plans to introduce the mammoths to Pleistocene Park, a wildlife reserve in Siberia. (Evolutionary biologist Beth Shapiro points out that "cloning" is a specific technique which cannot be accomplished without a living cell, none of which are available for mammoths, but suggests genome editing might be feasible.)

Although de-extinction efforts have not yet succeeded in producing viable offspring of a previously extinct species, the same process has been applied successfully to endangered species. The banteng is the second endangered species to be successfully cloned, and the first to survive for more than a week (the first was a gaur that died two days after being born). Scientists at Advanced Cell Technology in Worcester, Massachusetts, United States extracted DNA from banteng cells kept in the San Diego Zoo's "Frozen Zoo" facility, and transferred it into eggs from domestic cattle, a process called somatic cell nuclear transfer. Thirty hybrid embryos were created and sent to Trans Ova Genetics, which implanted the fertilized eggs in domestic cattle. Two were carried to term and delivered by Caesarian section. The first hybrid was born on April 1, 2003, and the second two days later. The second was euthanized, but the first survived and, as of September 2006, remained in good health at the San Diego Zoo.

Scientists from the University of Newcastle and the University of New South Wales, including Andrew French, Michael Mahony, Simon Clulow and Mike Archer reported in May 2013 the successful cloning of the extinct frog *Rheobatrachus silus* using the process of somatic cell nuclear transfer. The embryos developed for several days but died. In an important development the scientists from Newcastle reported associated technologies that provide a "proof of concept" for the proposal that frozen zoos (also referred to as genome banks and seed banks) are an effective mechanism to provide an insurance against species extinction and the loss of population genetic diversity. They connected the circle between de-extinction and the prevention of extinction for threatened animal species. The important advances were the capacity to successfully recover live frozen embryonic cells from animals that produce large yolky eggs (anamniotes such as fishes and amphibians) When this development is combined with somatic cell nuclear transfer (SCNT) it enables the genome to be recovered. The scientists point out that many embryonic cells can be frozen and when combined with frozen sperm storage enables the genetic diversity of populations to be stored. With groups of vertebrates such as the amphibians facing an extinction crisis they propose this as an effective means to prevent extinction while the causes of declines can be identified and remedied. The technical difference between frozen tissue samples commonly used for genetic studies (e.g. phylogenetic reconstruction) and those in a frozen zoo is the use of cryoprotectants and special freezing rates at the time of freezing and thawing.

Selective Breeding

The aurochs, which became extinct in 1627, could possibly be brought back by taking DNA samples from bone and teeth fragments in museums in order to obtain genetic material to recreate its DNA. Researchers would then compare the DNA to that of modern European cattle to determine which breeds still carry the creature's genes, and then undertake a selective breeding program to reverse the evolutionary process. The intention would be that with every passing generation, the cattle would more closely resemble the ancient aurochs.

The quagga, a subspecies of zebra which has been extinct since the 1880s, has been revived using selective breeding of zebras. Since the new animal is not genetically identical to the extinct subspecies, the new animal is called the Rau quagga.

Opposition

Opponents of de-extinction have claimed that efforts, and resources, to resurrect extinct species could have been better used trying to conserve endangered species that might themselves become extinct.

It has also been noted that a resurrected species, while being genetically the same as previously living specimens, will not have the same behaviour as its predecessors. The first animal to be brought back will be raised by parents of a different species (the fetus's host), not the one that died out and thus have differing mothering techniques and other behaviors.

Scientific American, in an editorial condemning de-extinction, pointed out that the technologies involved could have secondary applications, specifically to help species on the verge of extinction regain their genetic diversity, for example the black-footed ferret or the northern white rhinoceros. It noted, however, that such research "should be conducted under the mantle of preserving modern biodiversity rather than conjuring extinct species from the grave."

Other scholars have published ethical concerns regarding de-extinction. In *Conservation Biology*, Robert Sandler argues that introducing extinct species to environments may produce harm to modern species, as invasive species. Issues regarding scientific hubris, human and animal health, and the ecology of sensitive environments have been raised by the scientific community. Further research must be performed regarding de-extinction to investigate advantages and disadvantages to the technology. New technological practices must be examined to prevent environmental hazards.

Potential Candidates for De-extinction

Birds

- Passenger pigeon – this species numbered in the billions before being wiped out due to commercial hunting and habitat loss. Using DNA found in museum specimens and skins, the non-profit organization Revive and Restore aims to recreate the passenger pigeon using its closest living relative, the band-tailed pigeon.
- Moa – this group of large (up to 4 m [12 ft] tall and 110 kg [250 lb]), flightless birds became extinct in approximately 1400 AD following the arrival and proliferation of the Maori people on New Zealand; however, intact DNA from both preserved specimens and eggshells makes the moa a candidate for resurrection. New Zealand politician Trevor Mallard has suggested bringing back a medium-sized species.
- Heath hen – this subspecies of the prairie chicken became extinct on Martha's Vineyard in 1932 despite conservation efforts; however, the availability of usable DNA in museum specimens and protected areas in its former range makes this bird a possible candidate for de-extinction and reintroduction to its former habitat.
- Dodo – this large, flightless ground bird endemic to Mauritius became extinct in the 1640s due to exploitation by humans and due to introduced species such as rats and pigs, which ate their eggs. Due to a wealth of bones and some tissues, it is possible that this species may live again as it has a close relative in the surviving Nicobar pigeon.

- Elephant bird
- Huia
- Moho (‘Ō‘ō)

Mammals

- Woolly mammoth – The existence of preserved soft tissue remains and DNA of woolly mammoths has led to the idea that the species could be recreated by scientific means. Two methods have been proposed to achieve this. The first is cloning, which would involve removal of the DNA-containing nucleus of the egg cell of a female elephant, and replacement with a nucleus from woolly mammoth tissue. The cell would then be stimulated into dividing, and inserted back into a female elephant. The resulting calf would have the genes of the woolly mammoth, although its fetal environment would be different. To date, even the most intact mammoths have had little usable DNA because of their conditions of preservation. There is not enough to guide the production of an embryo.

  The second method involves artificially inseminating an elephant egg cell with sperm cells from a frozen woolly mammoth carcass. The resulting offspring would be an elephant–mammoth hybrid, and the process would have to be repeated so more hybrids could be used in breeding. After several generations of cross-breeding these hybrids, an almost pure woolly mammoth would be produced. The fact that sperm cells of modern mammals are potent for 15 years at most after deep-freezing is a hindrance to this method. In one case, an Asian elephant and an African elephant produced a live calf named Motty, but it died of defects at less than two weeks old.

  In 2008, a Japanese team found usable DNA in the brains of mice that had been frozen for 16 years. They hope to use similar methods to find usable mammoth DNA. In 2011, Japanese scientists announced plans to clone mammoths within six years. As the woolly mammoth genome has been mapped, a complete strand of DNA may be synthesised in the future. Mammoth expert Adrian Lister questions the ethics of such recreation attempts. In addition to the technical problems, he notes that there is not much habitat left that would be suitable for woolly mammoths. Because the species was gregarious, creating a few specimens would not be ideal. He also notes that the time and resources required would be enormous, and that the scientific benefits would be unclear; these resources should instead be used to preserve extant elephant species which are endangered. However, it was reported in March 2014 that blood recovered from a frozen mammoth carcass in 2013 now provides a “High chance” of cloning the woolly mammoth, despite previous hindrances.

Another way to revive the woolly mammoth would be to migrate genes from the mammoth genome into the genes of its closest living relative, the Asian elephant, to create hybridized animals with the notable adaptations that it had for living in a much colder environment than modern day elephants. This is currently being done by Harvard geneticist George Church, and they have already successfully made changes in the elephant genome with the genes that gave the woolly mammoth its cold-resistant blood, longer hair, and extra layer of fat.

A revived woolly mammoth or mammoth-elephant hybrid may find suitable habitat in the tundra and taiga forest ecozones, and may also find refuge in Pleistocene Park, a Pleistocene rewilding experiment by Russian scientist Sergey Zimov to recreate the mammoth steppe, the former habitat of the woolly mammoth. While mammoths are not required for the recreation of the steppe, they would be highly effective in doing so by quickly clearing brush and forest and allowing grasses to colonize the area, a capability that modern arctic megafauna do not have.

- Pyrenean ibex – This was one of four original subspecies of Spanish ibex that roamed on the Iberian peninsula. However, while it was abundant during Medieval times, over-hunting in the 19th and 20th centuries led to its demise. In 1999, only a single female named Celia was left alive in Ordesa National Park. Scientists captured her, took a tissue sample from her ear, collared her, then released her back into the wild, where she lived until she was found dead in 2000, having been crushed by a fallen tree. In 2003, scientists used the tissue sample to attempt to clone Celia and resurrect the extinct subspecies. Despite having successfully transferred nuclei from her cells into domestic goat egg cells and impregnating 208 female goats, only one came to term. The baby ibex that was born had a lung defect, and lived for only 7 minutes before suffocating from being incapable of breathing oxygen. Nevertheless, her birth was seen as a triumph and has been considered to have been the first de-extinction. However, in late 2013, scientists announced that they would again attempt to recreate the Pyrenean ibex. A problem to be faced, in addition to the many challenges of reproduction of a mammal by cloning, is that only females can be produced by cloning the female individual Celia, and no males exist for those females to reproduce with. This could potentially be addressed by breeding female clones with the closely related Southeastern Spanish ibex, and gradually creating a hybrid animal that will eventually bear more resemblance to the Pyrenean ibex than the Southeastern Spanish ibex.

- Aurochs – This species was widespread across Eurasia, North Africa, and the Indian subcontinent during the Pleistocene, but only the European aurochs (*Bos primigenius primigenius*) survived into historic times. This species is heavily featured in European cave paintings, such as Lascaux and Chauvet cave in France, and was still widespread during the Roman era, in which they were used as fighting animals for entertainment, and were noted by Julius Caesar for their strength and prowess. Following the fall of the Roman empire, however, overhunting of the aurochs by nobility and royalty caused its population to dwindle to a single population in the Jaktorów forest in Poland, where the last wild aurochs, a female, died of natural causes in 1627. However, because the aurochs is ancestral to most modern cattle breeds and has close relatives in primitive cattle breeds, it is possible for the aurochs (or a superficial ecological replacement) to be brought back through artificial selection. The first attempt at this was by Heinz and Lutz Heck to recreate the aurochs using modern cattle breeds, which resulted in the creation of Heck cattle. This breed has been introduced to nature preserves across Europe; however, it differs strongly from the aurochs in both physical characteristics and behavior, and modern attempts have tried to create an animal that is nearly identical to the aurochs in morphology, behavior, and even genetics. The TaurOs Project aims to recreate the aurochs through selectively breeding primitive cattle breeds over a course of twenty years to create a self-sufficient bovine grazer in herds of at least 150 animals in rewilded nature areas across Europe. This organization is partnered with the organization Rewilding Europe to help restore balance to European nature. A competing project to recreate the aurochs is the Uruz Project by the True Nature Foundation, which aims to recreate the aurochs through a more efficient breeding strategy and through genome editing, in order to decrease the number of generations of breeding needed and the ability to quickly eliminate undesired traits from the new aurochs population. It is hoped that the new aurochs will reinvigorate European nature by restoring its ecological role as a keystone species, and bring back biodiversity that disappeared following the decline of European megafauna, as well as helping to bring new economic opportunities related to European wildlife viewing.

- Quagga – This subspecies of the plains zebra was distinct in that it while it was striped on its face and upper torso, its rear abdomen was a solid brown. It was native to South Africa, but was wiped out in the wild due to over-hunting for sport, and the last individual died in 1883 in the Amsterdam zoo. However, since it is technically the same species as the surviving plains zebra, it has been argued that the quagga could be revived through artificial selection. The Quagga Project aims to recreate the quagga through the artificial selection of plains zebras, and aims to release these animals onto the western cape once an animal that fully resembles the quagga is achieved, which could have the benefit of eradicating non-native trees. Having started in 1984, the project now stands at 110 animals in 10 locations, and individuals have begun to show a reduction in stripes and a browning of the fur, owing to the success of the project.

- The Thylacine is commonly known as the Tasmanian tiger (because of its striped lower back) or the Tasmanian wolf. Native to continental Australia, Tasmania and New Guinea, it is believed to have become extinct in the 20th century. The thylacine had become extremely rare or extinct on the Australian mainland before British settlement of the continent, but it survived on the island of Tasmania along with several other endemic species, including the Tasmanian devil. Intensive hunting encouraged by bounties is generally blamed for its extinction, but other contributing factors may have been disease, the introduction of dogs, and human encroachment into its habitat. Despite its official classification as extinct, sightings are still reported, though none has been conclusively proven. The last know thylacine died at Beaumaris Zoo in Hobart, Tasmania, on 7 September 1936. It is believed to have died as the result of neglect—locked out of its sheltered sleeping quarters, it was exposed to a rare occurrence of extreme Tasmanian weather: extreme heat during the day and freezing temperatures at night. National Threatened Species Day has been held annually since 1996 on 7 September in Australia, to commemorate the death of the last officially recorded thylacine. Although there had been a conservation movement pressing for the thylacine's protection since 1901, driven in part by the increasing difficulty in obtaining specimens for overseas collections, political difficulties prevented any form of protection coming into force until 1936. Official protection of the species by the Tasmanian government was introduced on 10 July 1936, 59 days before the last known specimen died in captivity. The thylacine held the status of endangered species until the 1980s. International standards at the time stated that an animal could not be declared extinct until 50 years had passed without a confirmed record. Since no definitive proof of the thylacine's existence in the wild had been obtained for more than 50 years, it met that official criterion and was declared extinct by the International Union for Conservation of Nature in 1982 and by the Tasmanian government in 1986. The species was removed from Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 2013.

The Australian Museum in Sydney began a cloning project in 1999. The goal was to use genetic material from specimens taken and preserved in the early 20th century to clone new individuals and restore the species from extinction. Several molecular biologists have dismissed the project as a public relations stunt and its chief proponent, Mike Archer, received a 2002 nomination for the Australian Skeptics Bent Spoon Award for "the perpetrator of the most preposterous piece of paranormal or pseudo-scientific piffle." In late 2002, the researchers had some success as they were able to extract replicable DNA from the specimens. On 15 February 2005, the museum announced that it was stopping the project after tests showed the DNA retrieved from the specimens had been too badly degraded to be usable. In May 2005, Archer, the University of New South Wales Dean of Science at the time, former director of the Australian Museum and evolutionary biologist, announced that the project was being restarted by a group of interested universities and a research institute. The International Thylacine Specimen Database was completed in April 2005, and is the culmination of a four-year research project to catalog and digitally photograph, if possible, all known surviving thylacine specimen material held within museum, university and private collections. The master records are held by the Zoological Society of London. In 2008, researchers Andrew J. Pask and Marilyn B. Renfree from the University of Melbourne and Richard R. Behringer from the University of Texas at Austin reported that they managed to restore functionality of a gene *Col2A1 enhancer* obtained from 100-year-old ethanol-fixed thylacine tissues from museum collections. The genetic material was found working in transgenic mice. The research enhanced hopes of eventually restoring the population of thylacines. That same year, another group of researchers successfully sequenced the complete thylacine mitochondrial genome from two museum specimens. Their success suggests that it may be feasible to sequence the complete thylacine nuclear genome from museum specimens. Their results were published in the journal *Genome Research* in 2009. Mike Archer spoke about the possibilities of resurrecting the thylacine and the gastric-brooding frog at TED2013. Stewart Brand spoke at TED2013 about the ethics and possibilities of de-extinction, and made reference to thylacine in his talk.

- Cave lion – The discovery of two preserved cubs in the Sakha Republic ignited a project to clone the animal.
- Steppe bison – The discovery of the mummified steppe bison of 9,000 years ago could help people clone the ancient bison species back, even though the steppe bison won't be the first to be "resurrected".
- Toxodon – In 2015, a group of palaeontologists discovered the DNA of Toxodon and discovered that Toxodons were most closely related to today's horses and rhinos. Some people are planning to bring back Toxodons from extinction using a white rhinoceros as a surrogate mother.

Captive Breeding

Captive breeding is the process of breeding animals in controlled environments within well-defined settings, such as wildlife reserves, zoos and other commercial and non-commercial conservation facilities. Sometimes the process includes the release of individual organisms to the wild, when there is sufficient natural habitat to support new individuals or when the threat to the species in the wild is lessened. Captive breeding programs facilitate biodiversity and may save species from extinction. Release programs have the potential for diluting genetic diversity and fitness.

USFWS staff with two red wolf pups bred in captivity

History

Captive breeding has been successful in the past. The Pere David's deer was successfully saved through captive breeding programs after almost being hunted to extinction in China. Captive-breeding is employed by modern conservationists, and has saved a wide variety of species from extinction, ranging from birds (e.g., the pink pigeon), mammals (e.g., the pygmy hog), reptiles (e.g., the Round Island boa) and amphibians (e.g., poison arrow frogs). Their efforts were successful in reintroducing the Arabian oryx (under the auspices of the Fauna and Flora Preservation Society), in 1963. The Przewalski's horse was also successfully reintroduced in the wild after being bred in captivity.

Coordination

The breeding of endangered species is coordinated by cooperative breeding programs containing international studbooks and coordinators, who evaluate the roles of individual animals and institutions from a global or regional perspective. These studbooks contain information on birth date, gender, location, and lineage (if known), which helps determine survival and reproduction rates, number of founders of the population, and inbreeding coefficients. A species coordinator reviews the information in studbooks and determines a breeding strategy that would produce most advantageous offspring.

If two compatible animals are found at different zoos, the animals may be transported for mating, but this is stressful, which could in turn make mating less likely. However, this is still a popular breeding method among European zoological organizations. Artificial fertilization (by shipping semen) is another option, but male animals can experience stress during semen collection, and the same goes for females during the artificial insemination procedure. Furthermore, this approach yields lower-quality semen because shipping requires the life of the sperm to be extended for the transit time.

There are regional programmes for the conservation of endangered species:

- Americas: Species Survival Plan SSP (Association of Zoos and Aquariums AZA, Canadian Association of Zoos and Aquariums CAZA)
- Europe: European Endangered Species Programme EEP (European Association of Zoos and Aquaria EAZA)
- Australasia: Australasian Species Management Program ASMP (Zoo and Aquarium Association ZAA)
- Africa: African Preservation Program APP (African Association of Zoological Gardens and Aquaria PAAZAB)
- Japan: Conservation activities of Japanese Association of Zoos and Aquariums JAZA
- South Asia: Conservation activities of South Asian Zoo Association for Regional Cooperation SAZARC
- South East Asia: Conservation activities of South East Asian Zoos Association SEAZA

Challenges

Captive breeding techniques are usually difficult to implement for highly mobile species such as migratory birds like cranes and fishes like Hilsa.

Conservation biologists define endangered species as one that is likely to become extinct in the near future and is designated as endangered on the IUCN Red List. Conservation seeks to eliminate threats from human activities such as habitat loss and fragmentation, hunting, fishing, pollution, predation, disease, and parasitism.

Genetics

Recall that endangered species are those on the verge of extinction and so are more than a very small population. A risk of captive breeding includes inbreeding, i.e., mating between two closely related individuals as a result of a small gene pool. Inbreeding may lead to decreased disease immunity and phenotypic abnormalities. With the possibility of inbreeding, populations may undergo genetic drift, where genes have the potential to disappear completely, not only reducing genetic variation but also undermining natural selection by pressuring the remaining population and their predators. Over a sufficient number of generations, however, inbred populations can regain "normal" genetic diversity.

For example, since the 1970s the Matschie's tree-kangaroo, an endangered species, has been bred in captivity. The Tree Kangaroo Species Survival Plan (TKSSP) was established in 1992 to help with the management of Association of Zoos and Aquariums (AZA). TKSSP's annual breeding recommendations to preserve genetic diversity are based on mean kinship strategy (in order to retain adaptive potential and avoid inbreeding's disadvantages). In order to evaluate a captive breeding program's performance (in maintaining genetic diversity), researchers compare the genetic diversity of the captive breeding population to the wild population. According to McGreezy et al. (2010), "AZA Matschie tree kangaroo's haplotype diversity was almost two times lower than wild Matschie tree kangaroos". This difference with allele frequencies shows the changes that can happen over time, like genetic drift and mutation, when a species is taken out of its natural habitat.

Another example is the cheetah, the least genetically variable felid species. This makes it very difficult to pair animals in a way that would increase genetic diversity because all cheetahs are essentially genetically identical. It is also possible that human practices are causing even more of an inbreeding depression in the handling of the cats in zoos than exists within the wild populations. Note that although the cheetah has undergone genetic drift in the form of bottlenecks thousands of years ago, they seem to experience few of inbreeding's detrimental effects.

Behaviour Changes

Captive breeding can contribute to behavioural problems in animals that are subsequently released because they are unable to hunt or forage for food leading to starvation, possibly because the young animals spent the critical learning period in captivity. Released animals often do not avoid predators and are not able to find ample shelter for themselves and may die. Golden lion tamarin mothers often die in the wild before having offspring because they cannot climb and forage. This leads to continuing population declines despite reintroduction as the species are unable to produce viable offspring. Training can improve anti-predator skills, but its effectiveness varies.

Loss of Habitat

Another challenge with captive breeding is the habitat loss that occurs while they are in captivity being bred (though it is occurring even before they are captured). This may make release of the species nonviable if there is no habitat left to support larger populations.

Climate change and invasive species are threatening an increasing number of species with extinction. A decrease in population size can reduce genetic diversity, which detracts from a population's ability to adapt in a changing environment. In this way extinction risk is related to loss of genetic polymorphism, which is a difference in DNA sequence among individuals, groups or populations. Conservation programs can now obtain measurements of genetic diversity at functionally important genes thanks to advances in technology.

Assortative Mating

A study on mice has found that after captive breeding had been in place for multiple generations and these mice were “released” to breed with wild mice, that the captive-born mice bred amongst themselves instead of with the wild mice. This suggests that captive breeding may affect mating preferences, and has implications for the success of a reintroduction program.

Successes

The De Wildt Cheetah and Wildlife Centre, established in South Africa in 1971, has a cheetah captive breeding program. Between 1975 and 2005, 242 litters were born with a total of 785 cubs. The survival rate of cubs was 71.3% for the first twelve months and 66.2% for older cubs, validating the fact that cheetahs can be bred successfully (and their endangerment decreased). It also indicated that failure in other breeding habitats may be due to “poor” sperm morphology.

Wild Tasmanian devils have declined by 90% due to a transmissible cancer called Devil Facial Tumor Disease. A captive insurance population program has started, but the captive breeding rates at the moment are lower than they need to be. Keeley, Fanson, Masters, and McGreevy (2012) sought to “increase our understanding of the estrous cycle of the devil and elucidate potential causes of failed male-female pairings” by examining temporal patterns of fecal progestogen and corticosterone metabolite concentrations. They found that the majority of unsuccessful females were captive-born, suggesting that if the species’ survival depended solely on captive breeding, the population would probably disappear.

In 2010, the Oregon Zoo found that Columbia Basin pygmy rabbit pairings based on familiarity and preferences resulted in a significant increase in breeding success.

New Technologies

The major histocompatibility complex (MHC) is a genome region that is emerging as an exciting research field. Researchers found that genes that code for MHC affect the ability of certain species, such as *Batrachochytrium dendrobatidis*, to resist certain infections because the MHC has a mediating effect on the interaction between the body’s immune cells with other body cells. Measuring polymorphism at these genes can serve as an indirect measure of a population’s immunological fitness. Captive breeding programs that selectively breed for disease-resistant genes may facilitate successful reintroductions.

There have also been recent advances in captive breeding programs with the use of induced pluripotent stem cell (iPSC) technology, which has been tested on endangered species. Scientists hope that they can convert stem cells into germ cells in order to diversify the gene pools of threatened species. Healthy mice have been born with this technology. iPSC may one day be used to treat captive animals with diseases.

Ex Situ Conservation

Ex situ conservation literally means, "off-site conservation". It is the process of protecting an endangered species, variety or breed, of plant or animal outside of its natural habitat; for example, by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans. The degree to which humans control or modify the natural dynamics of the managed population varies widely, and this may include alteration of living environments, reproductive patterns, access to resources, and protection from predation and mortality. *Ex situ* management can occur within or outside a species' natural geographic range. Individuals maintained *ex situ* exist outside of an ecological niche. This means that they are not under the same selection pressures as wild populations, and they may undergo artificial selection if maintained *ex situ* for multiple generations.

Agricultural biodiversity is also conserved in *ex situ* collections. This is primarily in the form of gene banks where samples are stored in order to conserve the genetic resources of major crop plants and their wild relatives.

Facilities

Botanical Gardens, Zoos, and Aquaria

Botanical gardens, and zoos are the most conventional methods of ex situ conservation, all of which house whole, protected specimens for breeding and reintroduction into the wild when necessary and possible. These facilities provide not only housing and care for specimens of endangered species, but also have an educational value. They inform the public of the threatened status of endangered species and of those factors which cause the threat, with the hope of creating public interest in stopping and reversing those factors which jeopardize a species' survival in the first place. They are the most publicly visited ex situ conservation sites, with the WZCS (World Zoo Conservation Strategy) estimating that the 1100 organized zoos in the world receive more than 600 million visitors annually. Globally there is an estimated total of 2,107 aquaria and zoos in 125 countries. Additionally many private collectors or other not-for-profit groups hold animals and they engage in conservation or reintroduction efforts. Similarly there are approximately 2,000 botanical gardens in 148 counties cultivating or storing an estimated 80,000 taxa of plants.

Techniques for Plants

Cryopreservation

The storage of seeds, pollen, tissue, or embryos in liquid nitrogen. This method can be used for virtually indefinite storage of material without deterioration over a much greater time-period relative to all other methods of *ex situ* conservation. Cryopreservation is also used for the conservation of livestock genetics through Cryoconservation of animal genetic resources. Technical limitations prevent the cryopreservation of many species, but cryobiology is a field of active research, and many studies concerning plants are underway.

Seed Banking

The storage of seeds in a temperature and moisture controlled environment. This technique is used for taxa with orthodox seeds that tolerate desiccation. Seed bank facilities vary from sealed boxes to climate controlled walk-in freezers or vaults. Taxa with recalcitrant seeds that do not tolerate desiccation are typically not held in seed banks for extended periods of time.

Tissue Culture (Storage and Propagation)

Somatic tissue can be stored for short periods of time in vitro for short periods of time. This is done in a light and temperature controlled environment that regulates the growth of cells. As a e*x situ* conservation technique tissue culture is primary used for clonal propagation of vegetative tissue or immature seeds. This allows for the proliferation of clonal plants from a relatively small amount of parent tissue.

Field Gene Banking

An extensive open-air planting used maintain genetic diversity of wild, agricultural, or forestry species. Typically species that are either difficult or impossible to conserve in seed banks are conserved in field gene banks. Field gene banks may also be used grow and select progeny of species stored by other *ex situ* techniques.

Cultivation Collections

Plants under horticultural care in a constructed landscape, typically a botanic garden or arboreta. This technique is similar to a field gene bank in that plants are maintained in the ambient environment, but the collections are typically not as genetically diverse or extensive. These collections are susceptible to hybridization, artificial selection, genetic drift, and disease transmission. Species that cannot be conserved by other *ex situ* techniques are often included in cultivated collections.

Inter Situ

Plants are under horticulture care, but the environment is managed to near natural conditions. This occurs with either restored or semi-natural environments. This technique is primarily used for taxa that are rare or in areas where habitat has been severely degraded.

Techniques for Animals

Endangered animal species and breeds are preserved using similar techniques. Animal species can be preserved in genebanks, which consist of cryogenic facilities used to store living sperm, eggs, or embryos. For example, the Zoological Society of San Diego has established a "frozen zoo" to store such samples using cryopreservation techniques from more than 355 species, including mammals, reptiles, and birds.

A tank of liquid nitrogen, used to supply a cryogenic freezer (for storing laboratory samples at a temperature of about −150 °C).

A potential technique for aiding in reproduction of endangered species is interspecific pregnancy, implanting embryos of an endangered species into the womb of a female of a related species, carrying it to term. It has been carried out for the Spanish ibex.

Genetic Management of Captive Populations

Captive populations are subject to problems such as inbreeding depression, loss of genetic diversity and adaptations to captivity. It is important to manage captive populations in a way that minimizes these issues so that the individuals to be introduced will resemble the original founders as closely as possible, which will increase the chances of successful reintroductions. During the initial growth phase, the population size is rapidly expanded until a target population size is reached. The target population size is the number of individuals that are required to maintain appropriate levels of genetic diversity, which is generally considered to by 90% of the current genetic diversity after 100 years. The number of individuals required to meet this goal varies based on potential growth rate, effective size, current genetic diversity, and generation time. Once the target population size is reached, the focus shifts to maintaining the population and avoiding genetic issues within the captive population.

Minimizing Mean Kinship

Managing populations based on minimizing mean kinship values is often an effective way to increase genetic diversity and to avoid inbreeding within captive populations.

Kinship is the probability that two alleles will be identical by descent when one allele is taken randomly from each mating individual. The mean kinship value is the average kinship value between a given individual and every other member of the population. Mean kinship values can help determine which individuals should be mated. In choosing individuals for breeding, it is important to choose individuals with the lowest mean kinship values because these individuals are least related to the rest of the population and have the least common alleles. This ensures that rarer alleles are passed on, which helps to increase genetic diversity. It is also important to avoid mating two individuals with very different mean kinship values because such pairings propagate both the rare alleles that are present in the individual with the low mean kinship value as well as the common alleles that are present in the individual with the high mean kinship value. This genetic management technique requires that ancestry is known, so in circumstances where ancestry is unknown, it might be necessary to use molecular genetics such as microsatellite data to help resolve unknowns.

Avoiding Loss of Genetic Diversity

Genetic diversity is often lost within captive populations due to the founder effect and subsequent small population sizes. Minimizing the loss of genetic diversity within the captive population is an important component of *ex situ* conservation and is critical for successful reintroductions and the long term success of the species, since more diverse populations have higher adaptive potential. The loss of genetic diversity due to the founder effect can be minimized by ensuring that the founder population is large enough and genetically representative of the wild population. This is often difficult because removing large numbers of individuals from the wild populations may further reduce the genetic diversity of a species that is already of conservation concern. Maximizing the captive population size and the effective population size can decrease the loss of genetic diversity by minimizing the random loss of alleles due to genetic drift . Minimizing the number of generations in captivity is another effective method for reducing the loss of genetic diversity in captive populations.

Avoiding Adaptations to Captivity

Selection favors different traits in captive populations than it does in wild populations, so this may result in adaptations that are beneficial in captivity but are deleterious in the wild. This reduces the success of re-introductions, so it is important to manage captive populations in order to reduce adaptations to captivity. Adaptations to captivity can be reduced by minimizing the number of generations in captivity and by maximizing the number of migrants from wild populations. Minimizing selection on captive populations by creating an environment that is similar to their natural environment is another method of reducing adaptations to captivity, but it is important to find a balance between an environment that minimizes adaptation to captivity and an environment that permits adequate reproduction. Adaptations to captivity can also be reduced by managing the captive population as a series of population fragments. In this management strategy, the captive population is split into several sub-populations or fragments which are maintained separately. Smaller populations have lower adaptive potentials, so the population fragments are less likely to accumulate adaptations associated with captivity. The fragments are maintained separately until inbreeding becomes a concern. Immigrants are then exchanged between the fragments to reduce inbreeding, and then the fragments are managed separately again.

Managing Genetic Disorders

Genetic disorders are often an issue within captive populations due to the fact that the populations are usually established from a small number of founders. In large, outbreeding populations, the frequencies of most deleterious alleles are relatively low, but when a population undergoes a bottleneck during the founding of a captive population, previously rare alleles may survive and increase in number. Further inbreeding within the captive population may also increase the likelihood that deleterious alleles will be expressed due to increasing homozygosity within the population. The high occurrence of genetic disorders within a captive population can threaten both the survival of the captive population and its eventual reintroduction back into the wild. If the genetic disorder is dominant, it may be possible to eliminate the disease completely in a single generation by avoiding breeding of the affected individuals. However, if the genetic disorder is recessive, it may not be possible to completely eliminate the allele due to its presence in unaffected heterozygotes. In this case, the best option is to attempt to minimize the frequency of the allele by selectively choosing mating pairs. In the process of eliminating genetic disorders, it is important to consider that when certain individuals are prevented from breeding, alleles and therefore genetic diversity are removed from the population; if these alleles aren't present in other individuals, they may be lost completely. Preventing certain individuals from the breeding also reduces the effective population size, which is associated with problems such as the loss of genetic diversity and increased inbreeding.

Examples

Showy Indian clover, *Trifolium amoenum*, is an example of a species that was thought to be extinct, but was rediscovered in 1993 in the form of a single plant at a site in western Sonoma County. Seeds were harvested and currently grown in ex situ facilities.

The Wollemi pine is another example of a plant that is being preserved via *ex situ* conservation, as they are being grown in nurseries to be sold to the general public.

Drawbacks

Ex situ conservation, while helpful in humankind's efforts to sustain and protect our environment, is rarely enough to save a species from extinction. It is to be used as a last resort, or as a supplement to in situ conservation because it cannot recreate the habitat as a whole: the entire genetic variation of a species, its symbiotic counterparts, or those elements which, over time, might help a species adapt to its changing surroundings. Instead, *ex situ* conservation removes the species from its natural ecological contexts, preserving it under semi-isolated conditions whereby natural evolution and adaptation processes are either temporarily halted or altered by introducing the specimen to an unnatural habitat. In the case of cryogenic storage methods, the preserved specimen's adaptation processes are (quite literally) frozen altogether. The downside to this is that, when re-released, the species may lack the genetic adaptations and mutations which would allow it to thrive in its ever-changing natural habitat.

Furthermore, *ex situ* conservation techniques are often costly, with cryogenic storage being economically infeasible in most cases since species stored in this manner cannot provide a profit but instead slowly drain the financial resources of the government or organization determined to operate them. Seedbanks are ineffective for certain plant genera with recalcitrant seeds that do not remain fertile for long periods of time. Diseases and pests foreign to the species, to which the species has no natural defense, may also cripple crops of protected plants in *ex situ* plantations and in animals living in *ex situ* breeding grounds. These factors, combined with the specific environmental needs of many species, some of which are nearly impossible to recreate by man, make *ex situ* conservation impossible for a great number of the world's endangered flora and fauna.

In Situ Conservation

In-situ conservation is the on-site conservation or the conservation of genetic resources in natural populations of plant or animal species, such as forest genetic resources in natural populations of tree species. It is the process of protecting an endangered plant or animal species in its natural habitat, either by protecting or cleaning up the habitat itself, or by defending the species from predators. It is applied to conservation of agricultural biodiversity in agroecosystems by farmers, especially those using unconventional farming practices. e.g., Nilgiri biosphere in India.

Methods

Around 4% of the total geographical area of the country is used for *in situ* conservation. The following methods are presently used for *in situ* conservation.

In-situ conservation	Number available
Biosphere reserves	18
National parks	104
Wild-life sanctuaries	537

Biosphere Reserves

Biosphere reserves cover very large areas, often more than 5000 km^2. They are used to protect species for a long time.

Name	State
Nanda Devi	Uttrakhand
Nokrek	Meghalaya
Manas	Assam

National Parks

A national park is an area dedicated for the conservation of wildlife along with its environment. It is usually a small reserve covering an area of about 100 to 500 square kilometers. Within biosphere reserves, one or more national parks may also exist.

Name	State	Important wildlife
Kaziranga	Assam	One-horned rhino
Gir National Park	Gujarat	Asiatic lions
Bandipur	Karnataka	Elephant
Dachigam	J & K	Hangul
Kanha	M.P	Tiger
Periyar	Kerala	Tiger, elephant

Wild Sanctuaries

A wild sanctuary is an area which is reserved for the conservation of animals only. Currently, there are 492 wild sanctuaries.

Name	State	Major wildlife
Hazaribagh sanctuary	Jharkhand	Tiger, leopard
Ghana Bird sanctuary	Rajasthan	300 species of Birds
Sultanpur Bird Sanctuary	Haryana	Migratory birds
Abohar Wild life Sanctuary	Punjab	Black buck
Nal sarovar Bird Sanctuary	Gujarat	Water birds
Mudumalai Wild life Sanctuary	Tamil Nadu	Tiger, elephant, leopard
Vedanthangal Bird Sanctuary	Tamil Nadu	Water birds

Gene Sanctuary

A gene sanctuary is an area where plants are conserved. It includes both biosphere reserve as well as national park. India has set up its first gene sanctuary in the Garo Hills of Meghalaya for wild relatives of citrus. Efforts are also being made to set up gene sanctuaries for banana, sugarcane, rice and mango.

Community Reserves

It is the type of protected area introduced in Wildlife Protection Amendment Act 2002 to provide legal support to community or privately owned reserves which cannot be designated as national park or wildlife sanctuary.

Sacred Groves

They are tract of forest set aside where all the trees and wildlife within are venerated and given total protection.

Benefits

One benefit of *in situ* conservation is that it maintains recovering populations in the environment where they have developed their distinctive properties. Another benefit is that this strategy helps ensure the ongoing processes of evolution and adaptation within their environments. As a last resort, ex-situ conservation may be used on some or all of the population, when *in situ* conservation is too difficult, or impossible. The species gets adjusted to the natural disasters like drought, floods, forest fires and this method is very cheap and convenient.

Reserves

Wildlife and livestock conservation is mostly based on *in situ* conservation. This involves the protection of wildlife habitats. Also, sufficiently large reserves are maintained to enable the target species to exist in large numbers. The population size must be sufficient to enable the necessary genetic diversity to survive within the population, so that it has a good chance of continuing to adapt and evolve over time. This reserve size can be calculated for target species by examining the population density in naturally occurring situations. The reserves must then be protected from intrusion or destruction by man, and against other catastrophes.

Agriculture

In agriculture, *in situ conservation* techniques are an effective way to improve, maintain, and use traditional or native varieties of agricultural crops. Such methodologies link the positive output of scientific research with farmers' experience and field work.

First, the accessions of a variety stored at a germplasm bank and those of the same variety multiplied by farmers are jointly tested in the producers field and in the laboratory, under different situations and stresses. Thus, the scientific knowledge about the production characteristics of the native varieties is enhanced. Later, the best tested accessions are crossed, mixed, and multiplied under replicable situations. At last, these improved accessions are supplied to the producers. Thus, farmers are enabled to crop improved selections of their own varieties, instead of being lured to substitute their own varieties with commercial ones or to abandon their crop. This technique of conservation of agricultural biodiversity is more successful in marginal areas, where commercial varieties are not expedient, due to climate and soil fertility constraints. Or where the taste and cooking characteristics of traditional varieties compensate for their lower yields.

Conservation Genetics

Conservation genetics is an interdisciplinary science that aims to apply genetic methods to the conservation and restoration of biodiversity. Researchers involved in conservation genetics come from a variety of fields including population genetics, molecular ecology, biology, evolutionary biology, and systematics. Genetic diversity is one of the three fundamental levels of biodiversity, so it is directly important in conservation of biodiversity, though genetic factors are also important in the conservation of species and ecosystem diversity. Conservation of genetic variability is important to the overall health of populations because decreased genetic variability leads to increased levels of inbreeding, and reduced fitness.

Genetic Diversity

Genetic diversity is the variability of genes in a species. It can be estimated by the mean levels of heterozygosity in a population, the mean number of alleles per locus, or the percentage of polymorphic loci.

Importance of Genetic Diversity

If genetic diversity becomes low at many genes of a species, that species becomes increasingly at risk. It has only one possible choice of information at all or nearly all of its genes—in other words, all the individuals are nearly identical. If new pressures (such as environmental disasters) occur, a population with high genetic diversity has a greater chance of having at least some individuals with a genetic makeup that allows them to survive. If genetic diversity is very low, none of the individuals in a population may have the characteristics needed to cope with the new environmental conditions. Such a population could be suddenly wiped out.

The genetic diversity of a species is always open to change. No matter how many variants of a gene are present in a population today, only the variants that survive in the next generation can contribute to species diversity in the future. Once gene variants are lost, they cannot be recovered.

Contributors to Extinction

1. Inbreeding and inbreeding elevation which reduces the fitness of populations.

2. The accumulation of deleterious mutations
3. A decrease in frequency of heterozygotes in a population, or heterozygosity, which decreases a species' ability to evolve to deal with change in the environment.
4. Outbreeding depression
5. Fragmented populations
6. Taxonomic uncertainties, which can lead to a reprioritization of conservation efforts
7. Genetic drift as the main evolutionary process, instead of natural selection
8. Management units within species

Techniques

Specific genetic techniques are used to assess the genomes of a species regarding specific conservation issues as well as general population structure. This analysis can be done in two ways, with current DNA of individuals or historic DNA.

Techniques for analysing the differences between individuals and populations include

1. Alloenzymes
2. Random fragment length polymorphisms
3. Amplified fragment length polymorphisms
4. Random amplification of polymorphic DNA
5. Single strand conformation polymorphism
6. Minisatellites
7. Microsatellites
8. Single-nucleotide polymorphisms
9. Sequence analysis
10. DNA fingerprinting

These different techniques focus on different variable areas of the genomes within animals and plants. The specific information that is required determines which techniques are used and which parts of the genome are analysed. For example, mitochondrial DNA in animals has a high substitution rate, which makes it useful for identifying differences between individuals. However, it is only inherited in the female line, and the mitochondrial genome is relatively small. In plants, the mitochondrial DNA has very high rates of structural mutations, so is rarely used for genetic markers, as the chloroplast genome can be used instead. Other sites in the genome that are subject to high mutation rates such as the major histocompatibility complex, and the microsatellites and minisatellites are also frequently used.

These techniques can provide information on long-term conservation of genetic diversity and expound demographic and ecological matters such as taxonomy.

Another technique is using historic DNA for genetic analysis. Historic DNA is important because it allows geneticists to understand how species reacted to changes to conditions in the past. This is a key to understanding the reactions of similar species in the future.

Techniques using historic DNA include looking at preserved remains found in museums and caves. Museums are used because there is a wide range of species that are available to scientists all over the world. The problem with museums is that, historical perspectives are important because understanding how species reacted to changes in conditions in the past is a key to understanding reactions of similar species in the future. Evidence found in caves provides a longer perspective and does not disturb the animals.

Another technique that relies on specific genetics of an individual is noninvasive monitoring, which uses extracted DNA from organic material that an individual leaves behind, such as a feather. This too avoids disrupting the animals and can provide information about the sex, movement, kinship and diet of an individual.

Other more general techniques can be used to correct genetic factors that lead to extinction and risk of extinction. For example, when minimizing inbreeding and increasing genetic variation multiple steps can be taken. Increasing heterozygosity through immigration, increasing the generational interval through cryopreservation or breeding from older animals, and increasing the effective population size through equalization of family size all helps minimize inbreeding and its effects. Deleterious alleles arise through mutation, however certain recessive ones can become more prevalent due to inbreeding. Deleterious mutations that arise from inbreeding can be removed by purging, or natural selection. Populations raised in captivity with the intent of being reintroduced in the wild suffer from adaptations to captivity.

Inbreeding depression, loss of genetic diversity, and genetic adaptation to captivity are disadvantageous in the wild, and many of these issues can be dealt with through the aforementioned techniques aimed at increasing heterozygosity. In addition creating a captive environment that closely resembles the wild and fragmenting the populations so there is less response to selection also help reduce adaptation to captivity.

Solutions to minimize the factors that lead to extinction and risk of extinction often overlap because the factors themselves overlap. For example, deleterious mutations are added to populations through mutation, however the deleterious mutations conservation biologists are concerned with are ones that are brought about by inbreeding, because those are the ones that can be taken care of by reducing inbreeding. Here the techniques to reduce inbreeding also help decrease the accumulation of deleterious mutations.

Applications

These techniques have wide ranging applications. One application of these specific molecular techniques is in defining species and sub-species of salmonids. Hybridization is an especially important issue in salmonids and this has wide ranging conservation, political, social and economic implications. In Cutthroat Trout mtDNA and alloenzyme analysis, hybridization between native and non-native species was shown to be one of the major factors contributing to the decline in their populations. This led to efforts to remove some hybridized populations so native populations could breed more readily. Cases like these impact everything from the economy of local fishermen to larger companies, such as timber. Specific molecular techniques led to a closer analysis of taxonomic relationships, which is one factor that can lead to extinctions if unclear.

Implications

New technology in conservation genetics has many implications for the future of conservation biology. At the molecular level, new technologies are advancing. Some of these techniques include the analysis of minisatellites and MHC.These molecular techniques have wider effects from clarifying taxonomic relationships, as in the previous example, to determining the best individuals to reintroduce to a population for recovery by determining kinship. These effects then have consequences that reach even further. Conservation of species has implications for humans in the economic, social, and political realms. In the biological realm increased genotypic diversity has been shown to help ecosystem recovery, as seen in a community of grasses which was able to resist disturbance to grazing geese through greater genotypic diversity. Because species diversity increases ecosystem function, increasing biodiversity through new conservation genetic techniques has wider reaching effects than before.

A short list of studies a conservation geneticist may research include:

1. Phylogenetic classification of species, subspecies, geographic races, and populations, and measures of phylogenetic diversity and uniqueness.
2. Identifying hybrid species, hybridization in natural populations, and assessing the history and extent of introgression between species.
3. Population genetic structure of natural and managed populations, including identification of Evolutionary Significant Units (ESUs) and management units for conservation.

4. Assessing genetic variation within a species or population, including small or endangered populations, and estimates such as effective population size (Ne).
5. Measuring the impact of inbreeding and outbreeding depression, and the relationship between heterozygosity and measures of fitness.
6. Evidence of disrupted mate choice and reproductive strategy in disturbed populations.
7. Forensic applications, especially for the control of trade in endangered species.
8. Practical methods for monitoring and maximizing genetic diversity during captive breeding programs and re-introduction schemes, including mathematical models and case studies.
9. Conservation issues related to the introduction of genetically modified organisms.
10. The interaction between environmental contaminants and the biology and health of an organism, including changes in mutation rates and adaptation to local changes in the environment (e.g. industrial melanism).
11. New techniques for noninvasive genotyping.

Conservation Movement

The conservation movement, also known as nature conservation, is a political, environmental and a social movement that seeks to protect natural resources including animal and plant species as well as their habitat for the future.

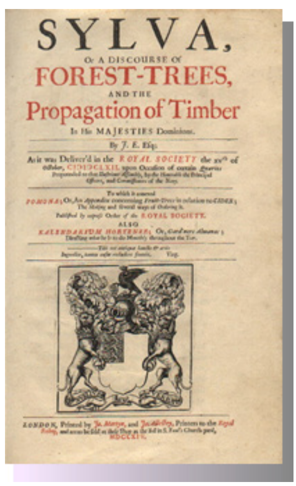
Much attention has been given to preserving the natural characteristics of Hopetoun Falls, Australia, while allowing ample access for visitors.

The early conservation movement included fisheries and wildlife management, water, soil conservation and sustainable forestry. The contemporary conservation movement has broadened from the early movement's emphasis on use of sustainable yield of natural resources and preservation of wilderness areas to include preservation of biodiversity. Some say the conservation movement is part of the broader and more far-reaching environmental movement, while others argue that they differ both in ideology and practice. Chiefly in the United States, conservation is seen as differing from environmentalism in that it aims to preserve natural resources expressly for their continued sustainable use by humans. In other parts of the world conservation is used more broadly to include the setting aside of natural areas and the active protection of wildlife for their inherent value, as much as for any value they may have for humans.

History

Early History

The conservation movement can be traced back to John Evelyn's work *Sylva*, presented as a paper to the Royal Society in 1662. Published as a book two years later, it was one of the most highly influential texts on forestry ever published. Timber resources in England were becoming dangerously depleted at the time, and Evelyn advocated the importance of conserving the forests by managing the rate of depletion and ensuring that the cut down trees get replenished.


SYLVA,
Or A DISCOURSE Of
FOREST-TREES,
AND THE
Propagation of Timber
In His MAJESTIES Dominions.

Sylva, or A Discourse of Forest-Trees and the Propagation of Timber in His Majesty's Dominions, title page of the first edition (1664).

The field developed during the 18th century, especially in Prussia and France where scientific forestry methods were developed. These methods were first applied rigorously in British India from the early-19th century. The government was interested in the use of forest produce and began managing the forests with measures to reduce the risk of wildfire in order to protect the "household" of nature, as it was then termed. This early ecological idea was in order to preserve the growth of delicate teak trees, which was an important resource for the Royal Navy. Concerns over teak depletion were raised as early as 1799 and 1805 when the Navy was undergoing a massive expansion during the Napoleonic Wars; this pressure led to the first formal conservation Act, which prohibited the felling of small teak trees. The first forestry officer was appointed in 1806 to regulate and preserve the trees necessary for shipbuilding. This promising start received a setback in the 1820s and 30s, when laissez-faire economics and complaints from private landowners brought these early conservation attempts to an end.

Origins of the Modern Conservation Movement

Conservation was revived in the mid-19th century, with the first practical application of scientific conservation principles to the forests of India. The conservation ethic that began to evolve included three core principles: that human activity damaged the environment, that there was a civic duty to maintain the environment for future generations, and that scientific, empirically based methods should be applied to ensure this duty was carried out. Sir James Ranald Martin was prominent in promoting this ideology, publishing many medico-topographical reports that demonstrated the scale of damage wrought through large-scale deforestation and desiccation, and lobbying extensively for the institutionalization of forest conservation activities in British India through the establishment of Forest Departments. Edward Percy Stebbing warned of desertification of India. The Madras Board of Revenue started local conservation efforts in 1842, headed by Alexander Gibson, a professional botanist who systematically adopted a forest conservation program based on scientific principles. This was the first case of state management of forests in the world.

These local attempts gradually received more attention by the British government as the unregulated felling of trees continued unabated. In 1850, the British Association in Edinburgh formed a committee to study forest destruction at the behest of Dr. Hugh Cleghorn a pioneer in the nascent conservation movement.

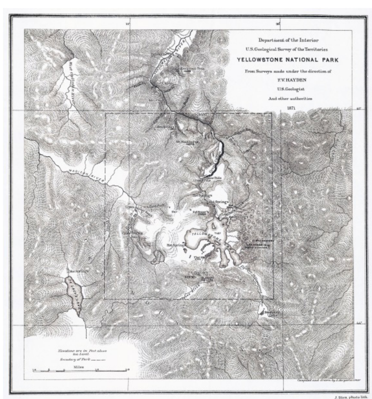
He had become interested in forest conservation in Mysore in 1847 and gave several lectures at the Association on the failure of agriculture in India. These lectures influenced the government under Governor-General Lord Dalhousie to introduce the first permanent and large-scale forest conservation program in the world in 1855, a model that soon spread to other colonies, as well the United States. In the same year, Cleghorn organised the Madras Forest Department and in 1860 the Department banned the use shifting cultivation. Cleghorn's 1861 manual, *The forests and gardens of South India*, became the definitive work on the subject and was widely used by forest assistants in the subcontinent. In 1861, the Forest Department extended its remit into the Punjab.

Sir Dietrich Brandis, a German forester, joined the British service in 1856 as superintendent of the teak forests of Pegu division in eastern Burma. During that time Burma's teak forests were controlled by militant Karen tribals. He introduced the "taungya" system, in which Karen villagers provided labour for clearing, planting and weeding teak plantations. After seven years in Burma, Brandis was appointed Inspector General of Forests in India, a position he served in for 20 years. He formulated new forest legislation and helped establish research and training institutions. The Imperial Forest School at Dehradun was founded by him.

Schlich, in the middle of the seated row, with students from the forestry school at Oxford, on a visit to the forests of Saxony in the year 1892.

Germans were prominent in the forestry administration of British India. As well as Brandis, Berthold Ribbentrop and Sir William P.D. Schlich brought new methods to Indian conservation, the latter becoming the Inspector-General in 1883 after Brandis stepped down. Schlich helped to establish the journal *Indian Forester* in 1874, and became the founding director of the first forestry school in England at Cooper's Hill in 1885. He authored the five-volume *Manual of Forestry* (1889–96) on silviculture, forest management, forest protection, and forest utilisation, which became the standard and enduring textbook for forestry students.

Conservation in the United States



F. V. Hayden's map of Yellowstone National Park, 1871.

The American movement received its inspiration from 19th century works that exalted the inherent value of nature, quite apart from human usage. Author Henry David Thoreau (1817-1862) made key philosophical contributions that exalted nature. Thoreau was interested in peoples' relationship with nature and studied this by living close to nature in a simple life. He published his experiences in the book *Walden,* which argued that people should become intimately close with nature. The ideas of Sir Brandis, Sir William P.D.

Schlich and Carl A. Schenck were also very influential - Gifford Pinchot, the first chief of the USDA Forest Service, relied heavily upon Brandis' advice for introducing professional forest management in the U.S. and on how to structure the Forest Service.

Both Conservationists and Preservationists appeared in political debates during the Progressive Era (the 1890s—early 1920s). There were three main positions. The laissez-faire position held that owners of private property—including lumber and mining companies, should be allowed to do anything they wished for their property.

The conservationists, led by future President Theodore Roosevelt and his close ally George Bird Grinnell, were motivated by the wanton waste that was taking place at the hand of market forces, including logging and hunting. This practice resulted in placing a large number of North American game species on the edge of extinction. Roosevelt recognized that the laissez-faire approach of the U.S. Government was too wasteful and inefficient. In any case, they noted, most of the natural resources in the western states were already owned by the federal government. The best course of action, they argued, was a long-term plan devised by national experts to maximize the long-term economic benefits of natural resources. To accomplish the mission, Roosevelt and Grinnell formed the Boone and Crockett Club in 1887. The Club was made up of the best minds and influential men of the day. The Boone and Crockett Club's contingency of conservationists, scientists, politicians, and intellectuals became Roosevelt's closest advisers during his march to preserve wildlife and habitat across North America. Preservationists, led by John Muir (1838–1914), argued that the conservation policies were not strong enough to protect the interest of the natural world because they continued to focus on the natural world as a source of economic production.

The debate between conservation and preservation reached its peak in the public debates over the construction of California's Hetch Hetchy dam in Yosemite National Park which supplies the water supply of San Francisco. Muir, leading the Sierra Club, declared that the valley must be preserved for the sake of its beauty: "No holier temple has ever been consecrated by the heart of man."

President Roosevelt put conservationist issue high on the national agenda. He worked with all the major figures of the movement, especially his chief advisor on the matter, Gifford Pinchot and was deeply committed to conserving natural resources. He encouraged the Newlands Reclamation Act of 1902 to promote federal construction of dams to irrigate small farms and placed 230 million acres (360,000 mi^2 or 930,000 km^2) under federal protection. Roosevelt set aside more federal land for national parks and nature preserves than all of his predecessors combined.

Gifford Pinchot had been appointed by McKinley as chief of Division of Forestry in the Department of Agriculture. In 1905, his department gained control of the national forest reserves. Pinchot promoted private use (for a fee) under federal supervision. In 1907, Roosevelt designated 16 million acres (65,000 km^2) of new national forests just minutes before a deadline.

A PRACTICAL FORESTER
(A subject that had attention all through Mr. Roosevelt's Presidency.)
From the *Pioneer Press* (St. Paul)

Roosevelt established the United States Forest Service, signed into law the creation of five national parks, and signed the year 1906 Antiquities Act, under which he proclaimed 18 new national monuments. He also established the first 51 bird reserves, four game preserves, and 150 national forests, including Shoshone National Forest, the nation's first. The area of the United States that he placed under public protection totals approximately 230,000,000 acres (930,000 km^2).

In May 1908, Roosevelt sponsored the Conference of Governors held in the White House, with a focus on natural resources and their most efficient use. Roosevelt delivered the opening address: "Conservation as a National Duty.".

In 1903 Roosevelt toured the Yosemite Valley with John Muir, who had a very different view of conservation, and tried to minimize commercial use of water resources and forests. Working through the Sierra Club he founded, Muir succeeded in 1905 in having Congress transfer the Mariposa Grove and Yosemite Valley to the federal government. While Muir wanted nature preserved for its own sake, Roosevelt subscribed to Pinchot's formulation, "to make the forest produce the largest amount of whatever crop or service will be most useful, and keep on producing it for generation after generation of men and trees."

Theodore Roosevelt's view on conservationism remained dominant for decades; - Franklin D. Roosevelt authorised the building of many large-scale dams and water projects, as well as the expansion of the National Forest System to buy out sub-marginal farms. In 1937, the Pittman–Robertson Federal Aid in Wildlife Restoration Act was signed into law, providing funding for state agencies to carry out their conservation efforts.

Since 1970

Environmental reemerged on the national agenda in 1970, with Republican Richard Nixon playing a major role, especially with his creation of the Environmental Protection Agency. The debates over the public lands and environmental politics played a supporting role in the decline of liberalism and the rise of modern environmentalism. Although Americans consistently rank environmental issues as "important", polling data indicates that in the voting booth voters rank the environmental issues low relative to other political concerns.

The growth of the Republican party's political power in the inland West (apart from the Pacific coast) was facilitated by the rise of popular opposition to public lands reform. Successful Democrats in the inland West and Alaska typically take more conservative positions on environmental issues than Democrats from the Coastal states. Conservatives drew on new organizational networks of think tanks, industry groups, and citizen-oriented organizations, and they began to deploy new strategies that affirmed the rights of individuals to their property, protection of extraction rights, to hunt and recreate, and to pursue happiness unencumbered by the federal government at the expense of resource conservation.

Areas of Concern

Deforestation and overpopulation are issues affecting all regions of the world. The consequent destruction of wildlife habitat has prompted the creation of conservation groups in other countries, some founded by local hunters who have witnessed declining wildlife populations first hand. Also, it was highly important for the conservation movement to solve problems of living conditions in the cities and the overpopulation of such places.

Boreal Forest and the Arctic

The idea of incentive conservation is a modern one but its practice has clearly defended some of the sub Arctic wildernesses and the wildlife in those regions for thousands of years, especially by indigenous peoples such as the Evenk, Yakut, Sami, Inuit and Cree. The fur trade and hunting by these peoples have preserved these regions for thousands of years. Ironically, the pressure now upon them comes from non-renewable resources such as oil, sometimes to make synthetic clothing which is advocated as a humane substitute for fur. (See Raccoon dog for case study of the conservation of an animal through fur trade.) Similarly, in the case of the beaver, hunting and fur trade were thought to bring about the animal's demise, when in fact they were an integral part of its conservation. For many years children's books stated and still do, that the decline in the beaver population was due to the fur trade. In reality however, the decline in beaver numbers was because of habitat destruction and deforestation, as well as its continued persecution as a pest (it causes flooding). In Cree lands however, where the population valued the animal for meat and fur, it continued to thrive. The Inuit defend their relationship with the seal in response to outside critics.

Latin America (Bolivia)

The Izoceño-Guaraní of Santa Cruz Department, Bolivia is a tribe of hunters who were influential in establishing the Capitania del Alto y Bajo Isoso (CABI). CABI promotes economic growth and survival of the Izoceno people while discouraging the rapid destruction of habitat within Bolivia's Gran Chaco. They are responsible for the creation of the 34,000 square kilometre Kaa-Iya del Gran Chaco National Park and Integrated

Management Area (KINP). The KINP protects the most biodiverse portion of the Gran Chaco, an ecoregion shared with Argentina, Paraguay and Brazil. In 1996, the Wildlife Conservation Society joined forces with CABI to institute wildlife and hunting monitoring programs in 23 Izoceño communities. The partnership combines traditional beliefs and local knowledge with the political and administrative tools needed to effectively manage habitats. The programs rely solely on voluntary participation by local hunters who perform self-monitoring techniques and keep records of their hunts. The information obtained by the hunters participating in the program has provided CABI with important data required to make educated decisions about the use of the land. Hunters have been willing participants in this program because of pride in their traditional activities, encouragement by their communities and expectations of benefits to the area.

Africa (Botswana)

In order to discourage illegal South African hunting parties and ensure future local use and sustainability, indigenous hunters in Botswana began lobbying for and implementing conservation practices in the 1960s. The Fauna Preservation Society of Ngamiland (FPS) was formed in 1962 by the husband and wife team: Robert Kay and June Kay, environmentalists working in conjunction with the Batawana tribes to preserve wildlife habitat.

The FPS promotes habitat conservation and provides local education for preservation of wildlife. Conservation initiatives were met with strong opposition from the Botswana government because of the monies tied to big-game hunting. In 1963, BaTawanga Chiefs and tribal hunter/adventurers in conjunction with the FPS founded Moremi National Park and Wildlife Refuge, the first area to be set aside by tribal people rather than governmental forces. Moremi National Park is home to a variety of wildlife, including lions, giraffes, elephants, buffalo, zebra, cheetahs and antelope, and covers an area of 3,000 square kilometers. Most of the groups involved with establishing this protected land were involved with hunting and were motivated by their personal observations of declining wildlife and habitat.

Pornography

Pornography (often abbreviated as "porn" or "porno" in informal usage) is the portrayal of sexual subject matter for the purpose of sexual arousal. Pornography may be presented in a variety of media, including books, magazines, postcards, photographs, sculpture, drawing, painting, animation, sound recording, film, video, and video games. The term applies to the depiction of the act rather than the act itself, and so does not include live exhibitions like sex shows and striptease. The primary subjects of pornographic depictions are pornographic models, who pose for still photographs, and pornographic actors or porn stars, who perform in pornographic films. If dramatic skills are not involved, a performer in a porn film may also be called a model.

XXX is used to designate pornographic material in the U.S. and other regions around the world.

Various groups within society have considered depictions of a sexual nature immoral, addictive, and noxious, labeling them pornographic, and attempting to have them suppressed under obscenity and other laws, with varying degrees of success. Such works have also often been subject to censorship and other legal restraints to publication, display, or possession. Such grounds, and even the definition of pornography, have differed in various historical, cultural, and national contexts.

Social attitudes towards the discussion and presentation of sexuality have become more tolerant and legal definitions of obscenity have become more limited, notably beginning in 1969 with *Blue Movie* by Andy Warhol, the first adult erotic film depicting explicit sex to receive wide theatrical release in the United States, and the subsequent Golden Age of Porn, leading to an industry for the production and consumption of pornography in the latter half of the 20th century. The introduction of home video and the Internet saw a boom in the worldwide porn industry that generates billions of dollars annually. Commercialized pornography accounts for over US$2.5 billion in the United States alone, including the production of various media and associated products and services. This industry employs thousands of performers along with support and production staff. It is also followed by dedicated industry publications and trade groups as well as the mainstream press, private organizations (watchdog groups), government agencies, and political organizations. More recently, sites such as Pornhub, RedTube, and YouPorn have served as repositories for home-made or semi-professional pornography, made available free by its creators (who could be called exhibitionists). It has presented a significant challenge to the commercial pornographic film industry.

Irrespective of the legal or social view of pornography, it has been used in a number of contexts. It is used, for example, at fertility clinics to stimulate sperm donors. Some couples use pornography at times for variety and to create a sexual interest or as part of foreplay. There is also some evidence that pornography can be used to treat voyeurism.

Etymology

The word is similar to the Modern Greek (*pornographia*), which de-rives from the Greek words πόρνη (*pornē* “prostitute” and *porneia* “prostitution”), and (*graphein* “to write or to record”, derived meaning “illustration”, cf. “graph”), and the suffix -ία (-*ia*, meaning “state of”, “property of”, or “place of”),thus meaning “a written description or illustration of prostitutes or prostitution”.

No date is known for the first use of the word in Greek; the earliest attested, most related word one could find in Greek, is *pornographos*, i.e. “someone writing of harlots”, in the *Deipnosophists* of Athenaeus. The Modern Greek word *pornographia* is a translation of the French *pornographie*.

“*Pornographie*” was in use in the French language during the 1800s. The word did not enter the English language as the familiar word until 1857 or as a French import in New Orleans in 1842.

History

Depictions of a sexual nature are older than civilization as depictions such as the venus figurines and rock art have existed since prehistoric times. However, the concept of pornography as understood today did not exist until the Victorian era. For example, the French Impressionism painting by Édouard Manet titled Olympia was a nude picture of a French courtesan, literally a “prostitute picture”. It was controversial at the time.

Oil lamp artifact depicting coitus more ferarum

Nineteenth-century legislation eventually outlawed the publication, retail, and trafficking of certain writings and images regarded as pornographic and would order the destruction of shop and warehouse stock meant for sale; however, the private possession of and viewing of (some forms of) pornography was not made an offence until recent times.

When large-scale excavations of Pompeii were undertaken in the 1860s, much of the erotic art of the Romans came to light, shocking the Victorians who saw themselves as the intellectual heirs of the Roman Empire. They did not know what to do with the frank depictions of sexuality and endeavored to hide them away from everyone but upper-class scholars. The moveable objects were locked away in the Secret Museum in Naples and what could not be removed was covered and cordoned off as to not corrupt the sensibilities of women, children, and the working classes.

Fanny Hill (1748) is considered "the first original English prose pornography, and the first pornography to use the form of the novel." It is an erotic novel by John Cleland first published in England as *Memoirs of a Woman of Pleasure*. It is one of the most prosecuted and banned books in history. The authors were charged with "corrupting the King's subjects."

The world's first law criminalizing pornography was the English Obscene Publications Act 1857 enacted at the urging of the Society for the Suppression of Vice. The Act, which applied to the United Kingdom and Ireland, made the sale of obscene material a statutory offence, giving the courts power to seize and destroy offending material. The American equivalent was the Comstock Act of 1873 which made it illegal to send any "obscene, lewd, and/or lascivious" materials through the mail. The English Act did not apply to Scotland, where the common law continued to apply. However, neither the English nor the United States Act defined what constituted "obscene", leaving this for the courts to determine. Prior to the English Act, the publication of obscene material was treated as a common law misdemeanour and effectively prosecuting authors and publishers was difficult even in cases where the material was clearly intended as pornography.

The Victorian attitude that pornography was for a select few can be seen in the wording of the Hicklin test stemming from a court case in 1868 where it asks, "whether the tendency of the matter charged as obscenity is to deprave and corrupt those whose minds are open to such immoral influences." Despite the fact of their suppression, depictions of erotic imagery were common throughout history.

Pornographic film production commenced almost immediately after the invention of the motion picture in 1895. Two of the earliest pioneers were Eugène Pirou and Albert Kirchner. Kirchner directed the earliest surviving pornographic film for Pirou under the trade name "Léar". The 1896 film *Le Coucher de la Mariée* showed Louise Willy performing a striptease. Pirou's film inspired a genre of risqué French films showing women disrobing and other filmmakers realised profits could be made from such films.

Sexually explicit films opened producers and distributors to prosecution. Those that were made were produced illicitly by amateurs starting in the 1920s, primarily in France and the United States. Processing the film was risky as was their distribution. Distribution was strictly private. In 1969, Denmark became the first country to abolish censorship, thereby decriminalizing pornography, which led to an explosion in investment and of commercially produced pornography. However, it continued to be banned in other countries, and had to be smuggled in, where it was sold "under the counter" or (sometimes) shown in "members only" cinema clubs. Nonetheless, and also in 1969, *Blue Movie* by Andy Warhol, was the first adult erotic film depicting explicit sex to receive wide theatrical release in the United States. The film was a seminal film in the Golden Age of Porn and, according to Warhol, a major influence in the making of *Last Tango in Paris*, an internationally controversial erotic drama film, starring Marlon Brando, and released a few years after *Blue Movie* was made.

The scholarly study of pornography, notably in cultural studies, is limited, perhaps due to the controversy about the topic in feminism. The first peer-reviewed academic journal about the study of pornography, *Porn Studies*, was published in 2014.

Classification

Pornography is often distinguished from erotica, which consists of the portrayal of sexuality with high-art aspirations, focusing also on feelings and emotions, while pornography involves the depiction of acts in a sensational manner, with the entire focus on the physical act, so as to arouse quick intense reactions.

Pornography is generally classified as either softcore or hardcore. A pornographic work is characterized as hardcore if it has any hardcore content, no matter how small. Both forms of pornography generally contain nudity. Softcore pornography generally contains nudity or partial nudity in sexually suggestive situations, but without explicit sexual activity, sexual penetration or "extreme" fetishism, while hardcore pornography may contain graphic sexual activity and visible penetration, including unsimulated sex scenes.

Subgenres

Pornography encompasses a wide variety of genres. Pornography featuring heterosexual acts composes the bulk of pornography and is "centred and invisible", marking the industry as heteronormative. However, a substantial portion of pornography is not normative, featuring more nonconventional forms of scenarios and sexual activity such as "'fat' porn, amateur porn, disabled porn, porn produced by women, queer porn, BDSM, and body modification."

Pornography can be classified according to the physical characteristics of the participants, fetish, sexual orientation, etc., as well as the types of sexual activity featured. Reality and voyeur pornography, animated videos, and legally prohibited acts also influence the classification of pornography. Pornography may fall into more than one genre. The genres of pornography are based on the type of activity featured and the category of participants, for example:

- Alt porn
- Amateur pornography
- Ethnic pornography
- Fetish pornography
- Group sex
- Reality pornography

- Sexual-orientation-based pornography
    - Straight porn
    - Gay pornography
    - Lesbian pornography
    - Bisexual pornography

Commercialism

Economics

Revenues of the adult industry in the United States are difficult to determine. In 1970, a Federal study estimated that the total retail value of hardcore pornography in the United States was no more than $10 million.

In 1998, Forrester Research published a report on the online "adult content" industry estimating $750 million to $1 billion in annual revenue. As an unsourced aside, the Forrester study speculated on an industry-wide aggregate figure of $8–10 billion, which was repeated out of context in many news stories, after being published in Eric Schlosser's book on the American black market. Studies in 2001 put the total (including video, pay-per-view, Internet and magazines) between $2.6 billion and $3.9 billion.

As of 2014, the porn industry was believed to bring in more than $13 billion on a yearly basis in the United States.

CNBC has estimated that pornography was a $13 billion industry in the USA, with $3,075 being spent on porn every second and a new porn video being produced every 39 minutes.

A significant amount of pornographic video is shot in the San Fernando Valley, which has been a pioneering region for producing adult films since the 1970s, and has since become home for various models, actors/actresses, production companies, and other assorted businesses involved in the production and distribution of pornography.

The pornography industry has been considered influential in deciding format wars in media, including being a factor in the VHS vs. Betamax format war (the videotape format war) and in the Blu-ray vs. HD DVD format war (the high-def format war).

Non-commercial Pornography

In addition to the porn industry, there is a large amount of non-commercial pornography. This should be distinguished from commercial pornography falsely marketed as featuring "amateurs".

Technology

Advancement

Pornographers have taken advantage of each technological advance in the production and distribution of pornography. They have used lithographs, the printing press, and photography. Pornography is considered a driving force in the development of technologies from the printing press, through photography (still and motion), to satellite TV, other forms of video, and the Internet. With the invention of tiny cameras and wireless equipments voyeur pornography is gaining ground. Mobile cameras are used to capture pornographic photos or videos, and forwarded as MMS, a practice known as sexting.

Computer-generated Images and Manipulations

Digital manipulation requires the use of source photographs, but some pornography is produced without human actors at all. The idea of completely computer-generated pornography was conceived very early as one of the most obvious areas of application for computer graphics and 3D rendering.

Until the late 1990s, digitally manipulated pornography could not be produced cost-effectively. In the early 2000s, it became a growing segment, as the modelling and animation software matured and the rendering capabilities of computers improved. As of 2004, computer-generated pornography depicting situations involving children and sex with fictional characters, such as Lara Croft, is already produced on a limited scale. The October 2004 issue of *Playboy* featured topless pictures of the title character from the *BloodRayne* video game.

3D Pornography

Due to the popularity of 3D blockbusters in theaters such as *Avatar* and *How to Train Your Dragon*, companies are now looking to shoot pornography movies in 3D. The first case of this occurred in Hong Kong, when a group of filmmakers filmed *3D Sex and Zen: Extreme Ecstasy* released in April 2011.

Production and Distribution by Region

The production and distribution of pornography are economic activities of some importance. The exact size of the economy of pornography and the influence that it has in political circles are matters of controversy.

In the United States, the sex film industry is centered in the San Fernando Valley of Los Angeles. In Europe, Budapest is regarded as the industry center.

Piracy, the illegal copying and distribution, of adult material is of great concern to the industry, the subject of litigation, and formalized anti-piracy efforts.

Study and Analysis

Effects

Research concerning the effects of pornography is concerned with multiple outcomes. Such research includes potential influences on rape, domestic violence, sexual dysfunction, difficulties with sexual relationships, and child sexual abuse. Viewers of novel and extreme pornographic images may become tolerant to such images, which may impact sexual response. Currently, there is no evidence that visual images and films are addictive. Several studies conclude the liberalization of porn in society may be associated with decreased rape and sexual violence rates, while others suggest no effect, or are inconclusive.

A 2012 academic study surveyed 308 young adult college women in romantic heterosexual relationships, examining the degree of correlation between their psychological and relational well-being and their partners' use of pornography. A negative correlation was found, which worsened for longer relationships in regard to the women's sexual satisfaction.

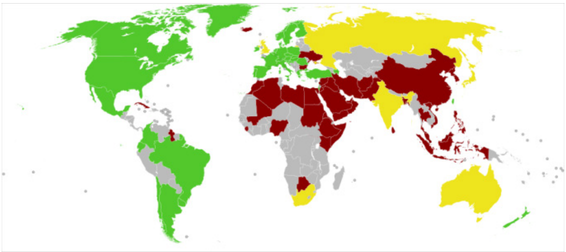
A following study examined the ways in which chronic porn use affects antecedents such as gender roles and levels of attachment among straight men in their romantic relationships. The study went on to link this to lower sexual satisfaction as well as a deterioration in the quality of the relationship. The point of pornographic content is to stimulate sexual desire, which as a result presents potential problems among couples. By porn affecting one's gender roles, this enables problems that affect the viewers psychologically, their views of their own sexuality, how others view their sexuality, and can cause self-inflicted or outward violence. An antecedent found to be affected by porn use by men was emotional attachment as well as attachment style in relationships, which can lead to physical and emotional issues among couples. The men in this study tended to avoid intimacy with their partner, which then led to even more porn use. This was also linked to heightened anxiety in the relationship. Men with lower anxiety tend to have a more stable level of attachment, whereas those who are unstable are either overly or not at all attached. Men who display less attachment and more avoidance also showed higher instances of casual sex and more frequent viewings of porn. This also meant that these men tended to avoid romantic or serious relationships, and the relationships they did engage in did not last long. The consequences of higher porn use by men in relationships showed a lower quality in their relationships and reduced satisfaction sexually, including displeasure with a partner's appearance, the act of sex, and intimacy. This then led to emotional feelings of shame and sometimes resentment.

A meta-analysis of 22 studies found that pornography "consumption was associated with sexual aggression in the United States and internationally, among males and females, and in cross-sectional and longitudinal studies. Associations were stronger for verbal than physical sexual aggression, although both were significant. The general pattern of results suggested that violent content may be an exacerbating factor."

Statistics

More than 70% of male internet users from 18 to 34 visit a pornographic site in a typical month. A 2009 study published in the *Journal of Economic Perspectives* found that Utah was the largest consumer of paid internet pornography per capita in the United States.

Legal Status



World map of pornography (18+) laws

Pornography legal

Pornography legal, but under some restrictions

Pornography illegal

Data unavailable

The legal status of pornography varies widely from country to country. Most countries allow at least some form of pornography. In some countries, softcore pornography is considered tame enough to be sold in general stores or to be shown on TV. Hardcore pornography, on the other hand, is usually regulated. The production and sale, and to a slightly lesser degree the possession, of child pornography is illegal in almost all countries, and some countries have restrictions on pornography depicting violence or animal pornography, or both.

Pornographic entertainment on display in a sex shop window. There is usually a minimum age to go into pornographic stores.

Most countries attempt to restrict minors' access to hardcore materials, limiting availability to sex shops, mail-order, and television channels that parents can restrict, among other means. There is usually an age minimum for entrance to pornographic stores, or the materials are displayed partly covered or not displayed at all. More generally, disseminating pornography to a minor is often illegal. Many of these efforts have been rendered practically irrelevant by widely available Internet pornography. A failed US law would have made these same restrictions apply to the internet.

In the United States, a person receiving unwanted commercial mail he or she deems pornographic (or otherwise offensive) may obtain a Prohibitory Order, either against all mail from a particular sender, or against all sexually explicit mail, by applying to the United States Postal Service. There are recurring urban legends of snuff movies, in which murders are filmed for pornographic purposes. Despite extensive work to ascertain the truth of these rumors, law enforcement officials have been unable to find any such works.

Some people, including pornography producer Larry Flynt and the writer Salman Rushdie, have argued that pornography is vital to freedom and that a free and civilized society should be judged by its willingness to accept pornography.

The UK government has criminalized possession of what it terms "extreme pornography" following the highly publicized murder of Jane Longhurst.

Child pornography is illegal in most countries, with a person most commonly being a child until the age of 18 (though the age does vary). In those countries, any film or photo with a child subject in a sexual act is considered pornography and illegal.

Pornography can infringe into basic human rights of those involved, especially when consent was not obtained. For example, revenge porn is a phenomenon where disgruntled sexual partners release images or video footage of intimate sexual activity, usually on the internet. In many countries there has been a demand to make such activities specifically illegal carrying higher punishments than mere breach of privacy or image rights, or circulation of prurient material. As a result, some jurisdictions have enacted specific laws against "revenge porn".

What is Not Pornography

In the U.S., a July 2014 criminal case decision in Massachusetts (COMMONWEALTH v. John REX.) made a legal determination of what was not to be considered "pornography" and in this particular case "child pornography". It was determined that photographs of naked children that were from sources such as National Geographic magazine, a sociology textbook, and a nudist catalog were not considered pornography in Massachusetts even while in the possession of a convicted and (at the time) incarcerated sex offender.

Copyright Status

In the United States, some courts have applied US copyright protection to pornographic materials. Although the first US copyright law specifically did not cover obscene materials, the provision was removed subsequently. Most pornographic works are theoretically work for hire meaning pornographic models do not receive statutory royalties for their performances. Of particular difficulty is the changing community attitudes of what is considered obscene, meaning that works could slip into and out of copyright protection based upon the prevailing standards of decency. This was not an issue with the copyright law up until 1972 when copyright protection required registration. When the law was changed to make copyright protection automatic, and for the life of the author.

Some courts have held that copyright protection effectively applies to works, whether they are obscene or not, but not all courts have ruled the same way. The copyright protection rights of pornography in the United States has again been challenged as late as February 2012.

Views on Pornography

Views and opinions of pornography come in a variety of forms and from a diversity of demographics and societal groups. Opposition of the subject generally, though not exclusively, comes from three main sources: law, feminism and religion.

A caricature on “the great epidemic of pornography, 19th-century French illustration.”

Feminist Views

Many feminists, including Andrea Dworkin and Catharine MacKinnon, argue that all pornography is demeaning to women or that it contributes to violence against women, both in its production and in its consumption. The production of pornography, they argue, entails the physical, psychological, or economic coercion of the women who perform in it, and where they argue that the abuse and exploitation of women is rampant;

in its consumption, they charge that pornography eroticizes the domination, humiliation and coercion of women, and reinforces sexual and cultural attitudes that are complicit in rape and sexual harassment. They charge that pornography presents a severely distorted image of sexual relations, and reinforces sex myths; that it always shows women as readily available and desiring to engage in sex at any time, with any man, on men's terms, always responding positively to any advances men make. They argue that because pornography often shows women enjoying and desiring to be violently attacked by men, saying "no" when they actually want sex, fighting back but then ending up enjoying the act – this can affect the public understanding of legal issues such as consent to sexual relations.

In contrast to these objections, other feminist scholars argue that the lesbian feminist movement in the 1980s was good for women in the porn industry. As more women entered the developmental side of the industry, this allowed women to gear porn more towards women because they knew what women wanted, both for actresses and the audience. This is believed to be a good thing because for such a long time, the porn industry has been directed by men for men. This also sparked the arrival of making lesbian porn for lesbians instead of men.

Furthermore, many feminists argue that the advent of VCR and consumer video allowed for the possibility of feminist pornography. Consumer video made it possible for the distribution and consumption of video pornography to locate women as legitimate consumers of pornography. Tristan Taormino says that feminist porn is "all about creating a fair working environment and empowering everyone involved." Feminist porn directors are interested in challenging representations of men and women, as well as providing sexually-empowering imagery that features many kinds of bodies.

In a 1995 essay for The New Yorker, writer Susan Faludi argued that porn was one of the few industries where women enjoy a power advantage in the workplace. "'Actresses have the power,' Alec Metro, one of the men in line, ruefully noted of the X-rated industry. A former firefighter who claimed to have lost a bid for a job to affirmative action, Metro was already divining that porn might not be the ideal career choice for escaping the forces of what he called 'reverse discrimination.' Female performers can often dictate which male actors they will and will not work with. '*They* make more money than *us*.' Porn – at least, porn produced for a heterosexual audience – is one of the few contemporary occupations where the pay gap operates in women's favor; the average actress makes fifty to a hundred per cent more money than her male counterpart. But then she is the object of desire; he is merely her appendage, the object of the object."

Religious Views

Religious organizations have been important in bringing about political action against pornography. In the United States, religious beliefs affect the formation of political beliefs that concern pornography.

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Habitat of Wildlife and its Conservation

A habitat is an environment that is inhabited by animals, plants and species. Habitat conservation is the conservation and protection of habitat areas. Habitat fragmentation, habitat cascade and habitat conservation are some of the topics that have been elucidated in the following text.

Habitat

A habitat is an ecological or environmental area that is inhabited by a particular species of animal, plant, or other type of organism. The term typically refers to the zone in which the organism lives and where it can find food, shelter, protection and mates for reproduction. It is the natural environment in which an organism lives, or the physical environment that surrounds a species population.

A habitat is made up of physical factors such as soil, moisture, range of temperature, and light intensity as well as biotic factors such as the availability of food and the presence or absence of predators. Every organism has certain habitat needs for the conditions in which it will thrive, but some are tolerant of wide variations while others are very specific in their requirements. A habitat is not necessarily a geographical area, it can be the interior of a stem, a rotten log, a rock or a clump of moss, and for a parasitic organism it is the body of its host, part of the host's body such as the digestive tract, or a single cell within the host's body.

This coral reef in the Phoenix Islands Protected Area is a rich habitat for sea life.

Few creatures make the ice shelves of Antarctica their habitat.
Ibex in alpine habitat

Habitat types include polar, temperate, subtropical and tropical. The terrestrial vegetation type may be forest, steppe, grassland, semi-arid or desert. Fresh water habitats include marshes, streams, rivers, lakes, ponds and estuaries, and marine habitats include salt marshes, the coast, the intertidal zone, reefs, bays, the open sea, the sea bed, deep water and submarine vents.

Habitats change over time. This may be due to a violent event such as the eruption of a volcano, an earthquake, a tsunami, a wildfire or a change in oceanic currents; or the change may be more gradual over millennia with alterations in the climate, as ice sheets and glaciers advance and retreat, and as different weather patterns bring changes of precipitation and solar radiation. Other changes come as a direct result of human activities; deforestation, the ploughing of ancient grasslands, the diversion and damming of rivers, the draining of marshland and the dredging of the seabed. The introduction of alien species can have a devastating effect on native wildlife, through increased predation, through competition for resources or through the introduction of pests and diseases to which the native species have no immunity.

Definition and Etymology

The word "habitat" has been in use since about 1755 and derives from the Latin third-person singular present indicative of *habitāre*, to inhabit, from *habēre*, to have or to hold. Habitat can be defined as the natural environment of an organism, the place in which it is natural for it to live and grow. It is similar in meaning to a biotope, an area of uniform environmental conditions associated with a particular community of plants and animals.

Environmental Factors

The chief environmental factors affecting the distribution of living organisms are temperature, humidity, climate, soil type and light intensity, and the presence or absence of all the requirements that the organism needs to sustain it. Generally speaking, animal communities are reliant on specific types of plant communities.

Some plants and animals are generalists, and their habitat requirements are met in a wide range of locations. The small white butterfly (*Pieris rapae*) for example is found on all the continents of the world apart from Antarctica. Its larvae feed on a wide range of *Brassicas* and various other plant species, and it thrives in any open location with diverse plant associations. The large blue butterfly is much more specific in its requirements; it is found only in chalk grassland areas, its larvae feed on *Thymus* species and because of complex lifecycle requirements it inhabits only areas in which *Myrmica* ants live.

Disturbance is important in the creation of biodiverse habitats. In the absence of disturbance, a climax vegetation cover develops that prevents the establishment of other species. Wildflower meadows are sometimes created by conservationists but most of the flowering plants used are either annuals or biennials and disappear after a few years in the absence of patches of bare ground on which their seedlings can grow. Lightning strikes and toppled trees in tropical forests allow species richness to be maintained as pioneering species move in to fill the gaps created. Similarly coastal habitats can become dominated by kelp until the seabed is disturbed by a storm and the algae swept away, or shifting sediment exposes new areas for colonisation. Another cause of disturbance is when an area may be overwhelmed by an invasive introduced species which is not kept under control by natural enemies in its new habitat.

Types of Habitat

Terrestrial habitat types include forests, grasslands, wetlands and deserts. Within these broad biomes are more specific habitats with varying climate types, temperature regimes, soils, altitudes and vegetation types. Many of these habitats grade into each other and each one has its own typical communities of plants and animals. A habitat may suit a particular species well, but its presence or absence at any particular location depends to some extent on chance, on its dispersal abilities and its efficiency as a coloniser.

Rich rainforest habitat in Dominica

Wetland habitats in Borneo

Freshwater habitats include rivers, streams, lakes, ponds, marshes and bogs. Although some organisms are found across most of these habitats, the majority have more specific requirements. The water velocity, its temperature and oxygen saturation are important factors, but in river systems, there are fast and slow sections, pools, bayous and backwaters which provide a range of habitats. Similarly, aquatic plants can be floating, semi-submerged, submerged or grow in permanently or temporarily saturated soils besides bodies of water. Marginal plants provide important habitat for both invertebrates and vertebrates, and submerged plants provide oxygenation of the water, absorb nutrients and play a part in the reduction of pollution.

Marine habitats include brackish water, estuaries, bays, the open sea, the intertidal zone, the sea bed, reefs and deep water zones. Further variations include rock pools, sand banks, mudflats, brackish lagoons, sandy and pebbly beaches, and seagrass beds, all supporting their own flora and fauna. The benthic zone or seabed provides a home for both static organisms, anchored to the substrate, and for a large range of organisms crawling on or burrowing into the surface. Some creatures float among the waves on the surface of the water, or raft on floating debris, others swim at a range of depths, including organisms in the demersal zone close to the seabed, and myriads of organisms drift with the currents and form the plankton.

Desert scene in Egypt

A desert is not the kind of habitat that favours the presence of amphibians, with their requirement for water to keep their skins moist and for the development of their young. Nevertheless, some frogs live in deserts, creating moist habitats underground and hibernating while conditions are adverse. Couch's spadefoot toad (*Scaphiopus couchii*) emerges from its burrow when a downpour occurs and lays its eggs in the transient pools that form; the tadpoles develop with great rapidity, sometimes in as little as nine days, undergo metamorphosis, and feed voraciously before digging a burrow of their own.

Other organisms cope with the drying up of their aqueous habitat in other ways. Vernal pools are ephemeral ponds that form in the rainy season and dry up afterwards. They have their specially-adapted characteristic flora, mainly consisting of annuals, the seeds of which survive the drought, but also some uniquely adapted perennials. Animals adapted to these extreme habitats also exist; fairy shrimps can lay "winter eggs" which are resistant to desiccation, sometimes being blown about with the dust, ending up in new depressions in the ground. These can survive in a dormant state for as long as fifteen years. Some killifish behave in a similar way; their eggs hatch and the juvenile fish grow with great rapidity when the conditions are right, but the whole population of fish may end up as eggs in diapause in the dried up mud that was once a pond.

Many animals and plants have taken up residence in urban environments. They tend to be adaptable generalists and use the town's features to make their homes. Rats and mice have followed man around the globe, pigeons, peregrines, sparrows, swallows and house martins use the buildings for nesting, bats use roof space for roosting, foxes visit the garbage bins and squirrels, coyotes, raccoons and skunks roam the streets. About 2,000 coyotes are thought to live in and around Chicago. A survey of dwelling houses in northern European cities in the twentieth century found about 175 species of invertebrate inside them, including 53 species of beetle, 21 flies, 13 butterflies and moths, 13 mites, 9 lice, 7 bees, 5 wasps, 5 cockroaches, 5 spiders, 4 ants and a number of other groups. In warmer climates, termites are serious pests in the urban habitat; 183 species are known to affect buildings and 83 species cause serious structural damage.

Microhabitats

A microhabitat is the small-scale physical requirements of a particular organism or population. Every habitat includes large numbers of microhabitats with subtly different exposure to light, humidity, temperature, air movement, and other factors. The lichens that grow on the north face of a boulder are different to those that grow on the south face, from those on the level top and those that grow on the ground nearby; the lichens growing in the grooves and on the raised surfaces are different from those growing on the veins of quartz. Lurking among these miniature "forests" are the microfauna, each species of invertebrate with its own specific habitat requirements.

There are numerous different microhabitats in a wood; coniferous forest, broad-leafed forest, open woodland, scattered trees, woodland verges, clearings and glades; tree trunk, branch, twig, bud, leaf, flower and fruit; rough bark, smooth bark, damaged bark, rotten wood, hollow, groove and hole; canopy, shrub layer, plant layer, leaf litter and soil; buttress root, stump, fallen log, stem base, grass tussock, fungus, fern and moss. The greater the structural diversity in the wood, the greater the number of microhabitats that will be present. A range of tree species with individual specimens of varying sizes and ages, and a range of features such as streams, level areas, slopes, tracks, clearings and felled areas will provide suitable conditions for an enormous number of biodiverse plants and animals. For example, in Britain it has been estimated that various types of rotting wood are home to over 1700 species of invertebrate.

For a parasitic organism, its habitat is the particular part of the outside or inside of its host on or in which it is adapted to live. The life cycle of some parasites involves several different host species, as well as free-living life stages, sometimes providing vastly different microhabitats. One such organism is the trematode (flatworm) *Microphallus turgidus*, present in brackish water marshes in the southeastern United States. Its first intermediate host is a snail and the second, a glass shrimp. The final host is the waterfowl or mammal that consumes the shrimp.

Extreme Habitats

Although the vast majority of life on Earth lives in mesophyllic (moderate) environments, a few organisms, most of them microbes, have managed to colonise extreme environments that are unsuitable for most higher life forms. There are bacteria, for example, living in Lake Whillans, half a mile below the ice of Antarctica; in the absence of sunlight, they must rely on organic material from elsewhere, perhaps decaying matter from glacier melt water or minerals from the underlying rock. Other bacteria can be found in abundance in the Mariana Trench, the deepest place in the ocean and on Earth; marine snow drifts down from the surface layers of the sea and accumulates in this undersea valley, providing nourishment for an extensive community of bacteria.

An Antarctic rock split apart to show an endolithic lifeform showing as a green layer a few millimetres thick

Other microbes live in habitats lacking in oxygen, and are dependent on chemical reactions other than photosynthesis. Boreholes drilled 300 m (1,000 ft) into the rocky seabed have found microbial communities apparently based on the products of reactions between water and the constituents of rocks. These communities have been little studied, but may be an important part of the global carbon cycle. Rock in mines two miles deep also harbour microbes; these live on minute traces of hydrogen produced in slow oxidizing reactions inside the rock. These metabolic reactions allow life to exist in places with no oxygen or light, an environment that had previously been thought to be devoid of life.

The intertidal zone and the photic zone in the oceans are relatively familiar habitats. However the vast bulk of the ocean is unhospitable to air-breathing humans, with scuba divers limited to the upper 50 m (160 ft) or so. The lower limit for photosynthesis is 100 to 200 m (330 to 660 ft) and below that depth the prevailing conditions include total darkness, high pressure, little oxygen (in some places), scarce food resources and extreme cold. This habitat is very challenging to research, and as well as being little studied, it is vast, with 79% of the Earth's biosphere being at depths greater than 1,000 m (3,300 ft). With no plant life, the animals in this zone are either detritivores, reliant on food drifting down from surface layers, or they are predators, feeding on each other. Some organisms are pelagic, swimming or drifting in mid-ocean, while others are benthic, living on or near the seabed. Their growth rates and metabolisms tend to be slow, their eyes may be very large to detect what little illumination there is, or they may be blind and rely on other sensory inputs. A number of deep sea creatures are bioluminescent; this serves a variety of functions including predation, protection and social recognition. In general, the bodies of animals living at great depths are adapted to high pressure environments by having pressure-resistant biomolecules and small organic molecules present in their cells know as piezolytes, which give the proteins the flexibility they need. There are also unsaturated fats in their membranes which prevent them from solidifying at low temperatures.

Dense mass of white crabs at a hydrothermal vent, with stalked barnacles on right

Hydrothermal vents were first discovered in the ocean depths in 1977. They result from seawater becoming heated after seeping through cracks to places where hot magma is close to the seabed. The under-water hot springs may gush forth at temperatures of over 340 °C (640 °F) and support unique communities of organisms in their immediate vicinity. The basis for this teeming life is chemosynthesis, a process by which microbes convert such substances as hydrogen sulfide or ammonia into organic molecules. These bacteria and Archaea are the primary producers in these ecosystems and support a diverse array of life. About 350 species of organism, dominated by molluscs, polychaete worms and crustaceans, had been discovered around hydrothermal vents by the end of the twentieth century, most of them being new to science and endemic to these habitats.

Besides providing locomotion opportunities for winged animals and a conduit for the dispersal of pollen grains, spores and seeds, the atmosphere can be considered to be a habitat in its own right. There are metabolically active microbes present that actively reproduce and spend their whole existence airborne, with hundreds of thousands of individual organisms estimated to be present in a cubic metre of air. The airborne microbial community may be as diverse as that found in soil or other terrestrial environments, however these organisms are not evenly distributed, their densities varying spatially with altitude and environmental conditions. Aerobiology has been little studied, but there is evidence of nitrogen fixation in clouds, and less clear evidence of carbon cycling, both facilitated by microbial activity.

There are other examples of extreme habitats where specially adapted lifeforms exist; tar pits teeming with microbial life; naturally occurring crude oil pools inhabited by the larvae of the petroleum fly; hot springs where the temperature may be as high as 71 °C (160 °F) and cyanobacteria create microbial mats; cold seeps where the methane and hydrogen sulfide issue from the ocean floor and support microbes and higher animals such as mussels which form symbiotic associations with these anaerobic organisms; salt pans harbour salt-tolerant microorganisms and also *Wallemia ichthyophaga*, a basidomycotous fungus; ice sheets in Antarctica which support fungi *Thelebolus* spp., and snowfields on which algae grow.

Habitat Change

Whether from natural processes or the activities of man, landscapes and their associated habitats change over time. There are the slow geomorphological changes associated with the geologic processes that cause tectonic uplift and subsidence, and the more rapid changes associated with earthquakes, landslides, storms, flooding, wildfires, coastal erosion, deforestation and changes in land use. Then there are the changes in habitats brought on by alterations in farming practices, tourism, pollution, fragmentation and climate change.

Twenty five years after the devastating eruption at Mount St. Helens, United States, pioneer species have moved in.

Loss of habitat is the single greatest threat to any species. If an island on which an endemic organism lives becomes uninhabitable for some reason, the species will become extinct. Any type of habitat surrounded by a different habitat is in a similar situation to an island. If a forest is divided into parts by logging, with strips of cleared land separating woodland blocks, and the distances between the remaining fragments exceeds the distance an individual animal is able to travel, that species becomes especially vulnerable. Small populations generally lack genetic diversity and may be threatened by increased predation, increased competition, disease and unexpected catastrophe. At the edge of each forest fragment, increased light encourages secondary growth of fast-growing species and old growth trees are more vulnerable to logging as access is improved. The birds that nest in their crevices, the epiphytes that hang from their branches and the invertebrates in the leaf litter are all adversely affected and biodiversity is reduced. Habitat fragmentation can be ameliorated to some extent by the provision of wildlife corridors connecting the fragments. These can be a river, ditch, strip of trees, hedgerow or even an underpass to a highway. Without the corridors, seeds cannot disperse and animals, especially small ones, cannot travel through the hostile territory, putting populations at greater risk of local extinction.

Habitat disturbance can have long-lasting effects on the environment. *Bromus tectorum* is a vigorous grass from Europe which has been introduced to the United States where it has become invasive. It is highly adapted to fire, producing large amounts of flammable detritus and increasing the frequency and intensity of wildfires. In areas where it has become established, it has altered the local fire regimen to such an extant that native plants cannot survive the frequent fires, allowing it to become even more dominant. A marine example is when sea urchin populations “explode” in coastal waters and destroy all the macroalgae present. What was previously a kelp forest becomes an urchin barren that may last for years and this can have a profound effect on the food chain. Removal of the sea urchins, by disease for example, can result in the seaweed returning, with an over-abundance of fast-growing kelp.

Habitat Protection

The protection of habitats is a necessary step in the maintenance of biodiversity because if habitat destruction occurs, the animals and plants reliant on that habitat suffer. Many countries have enacted legislation to protect their wildlife. This may take the form of the setting up of national parks, forest reserves and wildlife reserves, or it may restrict the activities of humans with the objective of benefiting wildlife. The laws may be designed to protect a particular species or group of species, or the legislation may prohibit such activities as the collecting of bird eggs, the hunting of animals or the removal of plants. A general law on the protection of habitats may be more difficult to implement than a site specific requirement. A concept introduced in the Unites States in 1973 involves protecting the critical habitat of endangered species, and a similar concept has been incorporated into some Australian legislation.

International treaties may be necessary for such objectives as the setting up of marine reserves. Another international agreement, the Convention on the Conservation of

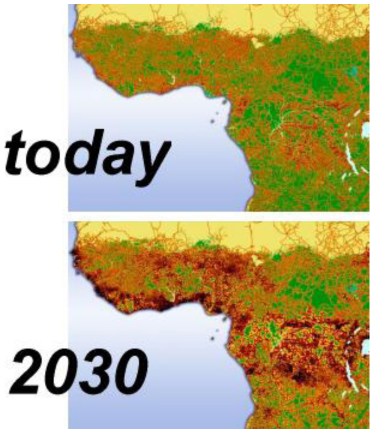
Migratory Species of Wild Animals, protects animals that migrate across the globe and need protection in more than one country. However, the protection of habitats needs to take into account the needs of the local residents for food, fuel and other resources. Even where legislation protects the environment, a lack of enforcement often prevents effective protection. Faced with food shortage, a farmer is likely to plough up a level patch of ground despite it being the last suitable habitat for an endangered species such as the San Quintin kangaroo rat, and even kill the animal as a pest. In this regard, it is desirable to educate the community on the uniqueness of their flora and fauna and the benefits of ecotourism.

Monotypic Habitat

A monotypic habitat is one in which a single species of animal or plant is so dominant as to virtually exclude all other species. An example would be sugarcane; this is planted, burnt and harvested, with herbicides killing weeds and pesticides controlling invertebrates. The monotypic habitat occurs in botanical and zoological contexts, and is a component of conservation biology. In restoration ecology of native plant communities or habitats, some invasive species create monotypic stands that replace and/or prevent other species, especially indigenous ones, from growing there. A dominant colonization can occur from retardant chemicals exuded, nutrient monopolization, or from lack of natural controls such as herbivores or climate, that keep them in balance with their native habitats. The yellow starthistle, *Centaurea solstitialis*, is a botanical monotypic-habitat example of this, currently dominating over 15,000,000 acres (61,000 km^2) in California alone. The non-native freshwater zebra mussel, *Dreissena polymorpha*, that colonizes areas of the Great Lakes and the Mississippi River watershed, is a zoological monotypic-habitat example; the predators that control it in its home-range in Russia are absent and it proliferates abundantly. Even though its name may seem to imply simplicity as compared with polytypic habitats, the monotypic habitat can be complex. Aquatic habitats, such as exotic *Hydrilla* beds, support a similarly rich fauna of macroinvertebrates to a more varied habitat, but the creatures present may differ between the two, affecting small fish and other animals higher up the food chain.

Habitat Fragmentation

Habitat fragmentation describes the emergence of discontinuities (fragmentation) in an organism's preferred environment (habitat), causing population fragmentation and ecosystem decay. Habitat fragmentation can be caused by geological processes that slowly alter the layout of the physical environment (suspected of being one of the major causes of speciation), or by human activity such as land conversion, which can alter the environment much faster and causes extinctions of many species.



Fragmentation and destruction of Great Ape habitat in Central Africa, from the GLOBIO and GRASP projects.

Deforestation and increased road-building in the Amazon Rainforest are a significant concern because of increased human encroachment upon wild areas, increased resource extraction and further threats to biodiversity.

Definition

The term habitat fragmentation includes five discrete phenomena:

- Reduction in the total area of the habitat
- Decrease of the interior: edge ratio
- Isolation of one habitat fragment from other areas of habitat
- Breaking up of one patch of habitat into several smaller patches
- Decrease in the average size of each patch of habitat

"fragmentation ... not only causes loss of the amount of habitat, but by creating small, isolated patches it also changes the properties of the remaining habitat" (van den Berg et al. 2001). Habitat fragmentation is the landscape level of the phenomenon, and patch level process. Thus meaning, it covers; the patch areas, edge effects, and patch shape complexity.

Natural Causes

Evidence of habitat destruction through natural processes such as volcanism, fire, and climate change is found in the fossil record. For example, habitat fragmentation of tropical rainforests in Euramerica 300 million years ago led to a great loss of amphibian diversity, but simultaneously the drier climate spurred on a burst of diversity among reptiles.

Human Causes

Habitat fragmentation is frequently caused by humans when native vegetation is cleared for human activities such as agriculture, rural development, urbanization and the creation of hydroelectric reservoirs. Habitats which were once continuous become divided into separate fragments. After intensive clearing, the separate fragments tend to be very small islands isolated from each other by cropland, pasture, pavement, or even barren land. The latter is often the result of slash and burn farming in tropical forests. In the wheat belt of central western New South Wales, Australia, 90% of the native vegetation has been cleared and over 99% of the tall grass prairie of North America has been cleared, resulting in extreme habitat fragmentation.

Implications

One of the major ways that habitat fragmentation affects biodiversity is by reducing the amount of suitable habitat available for organisms. Habitat fragmentation often involves both habitat destruction and the subdivision of previously continuous habitat. Plants and other sessile organisms are disproportionately affected by some types of habitat fragmentation because they cannot respond quickly to the altered spatial configuration of the habitat.

As the remaining habitat patches are smaller, they tend to support smaller populations of species. Small populations are at an increased risk of a variety of genetic consequences that influence their long-term survival. Remnant populations often contain only a subset of the genetic diversity found in the previously continuous habitat. Processes that act upon underlying genetic diversity such as adaptation have a smaller pool of fitness-maintaining alleles to survive in the face of environmental change.

Populations can maintain genetic diversity through migration. In continuous habitats, migrants have few barriers to establish themselves in suitable sites. In fragmented habitats however, the separation between suitable sites disrupts migration, and therefore gene flow, limiting a populations capacity to supplement the reduced genetic diversity of the remnant populations. With lower migration, inbreeding becomes a of increasing concern as the level of homozygosity increases, facilitating the expression of deleterious alleles that reduce the fitness of the population called inbreeding depression.

The percentage preservation of contiguous habitats is closely related to both genetic and species biodiversity preservation. Generally a 10% remnant contiguous habitat will result in a 50% biodiversity loss.

Reduced Viability

Area is the primary determinant of the number of species in a fragment. Minor fluctuations in climate, resources, or other factors that would be unremarkable and quickly corrected in large populations can be catastrophic in small, isolated populations. Thus fragmentation of habitat is an important cause of species extinction. Population dynamics of subdivided populations tend to vary asynchronously. In an unfragmented landscape a declining population can be “rescued” by immigration from a nearby expanding population. In fragmented landscapes, the distance between fragments may prevent this from happening. Additionally, unoccupied fragments of habitat that are separated from a source of immigrants by some barrier are less likely to be repopulated than adjoining fragments. Even small species such as the Columbia spotted frog are reliant on the rescue effect. Studies showed 25% of juveniles travel a distance over 200m compared to 4% of adults. Of these, 95% remain in their new locale, demonstrating that this journey is necessary for survival.

Habitat fragmented by numerous roads near the Indiana Dunes National Lakeshore.

Additionally, habitat fragmentation leads to edge effects. Microclimatic changes in light, temperature and wind can alter the ecology around the fragment, and in the interior and exterior portions of the fragment. Fires become more likely in the area as humidity drops and temperature and wind levels rise. Exotic and pest species may establish themselves easily in such disturbed environments, and the proximity of domestic animals often upsets the natural ecology. Also, habitat along the edge of a fragment has a different climate and favours different species from the interior habitat. Small fragments are therefore unfavourable for species which require interior habitat.

Conservation Implications

Habitat fragmentation is often a cause of species becoming threatened or endangered. The existence of viable habitat is critical to the survival of any species, and in many cases the fragmentation of any remaining habitat can lead to difficult decisions for conservation biologists. Given a limited amount of resources available for conservation is it preferable to protect the existing isolated patches of habitat or to buy back land to get the largest possible continuous piece of land? This ongoing debate is often referred to as SLOSS (Single Large or Several Small).

One solution to the problem of habitat fragmentation is to link the fragments by preserving or planting corridors of native vegetation. This has the potential to mitigate the problem of isolation but not the loss of interior habitat. In rare cases a conservation reliant species may gain some measure of disease protection by being distributed in isolated habitats.

Another mitigation measure is the enlargement of small remnants in order to increase the amount of interior habitat. This may be impractical since developed land is often more expensive and could require significant time and effort to restore.

The best solution is generally dependent on the particular species or ecosystem that is being considered. More mobile species, like most birds, do not need connected habitat while some smaller animals, like rodents, may be more exposed to predation in open land. These questions generally fall under the headings of metapopulations island biogeography.

Forest Fragmentation

Forest fragmentation is a form of habitat fragmentation where forests are reduced (either naturally or man-made) to relatively small, isolated patches of forest known as forest fragments or forest remnants. The intervening matrix that separates the remaining woodland patches can be natural open areas, farmland, or developed areas. Following the principles of island biogeography, remnant woodlands act like islands of forest in a sea of pastures, fields, subdivisions, shopping malls, etc. These fragments will then begin to undergo the process of ecosystem decay.

Implications

Forest fragmentation is one of the greatest threats to biodiversity in forests, especially in the tropics. The problem of habitat destruction that caused the fragmentation in the first place is compounded by:

- the inability of individual forest fragments to support viable populations, especially of large vertebrates
- the local extinction of species that do not have at least one fragment capable of supporting a viable population
- edge effects that alter the conditions of the outer areas of the fragment, greatly reducing the amount of true forest interior habitat.

The effect of fragmentation on the flora and fauna of a forest patch depends on a) the size of the patch, and b) its degree of isolation. Isolation depends on the distance to the nearest similar patch, and the contrast with the surrounding areas. For example, if a cleared area is reforested or allowed to regenerate, the increasing structural diversity of the vegetation will lessen the isolation of the forest fragments. However, when formerly forested lands are converted permanently to pastures, agricultural fields, or human-inhabited developed areas, the remaining forest fragments, and the biota within them, are often highly isolated.

Forest patches that are smaller or more isolated will lose species faster than those that are larger or less isolated. A large number of small forest "islands" typically cannot support the same biodiversity that a single contiguous forest would hold, even if their combined area is much greater than the single forest. However, forest islands in rural landscapes greatly increase their biodiversity.

Habitat Conservation

Habitat conservation is a management practice that seeks to conserve, protect and restore habitat areas for wild plants and animals, especially conservation reliant species, and prevent their extinction, fragmentation or reduction in range. It is a priority of many groups that cannot be easily characterized in terms of any one ideology.

Tree planting is an aspect of habitat conservation. In each plastic tube a hardwood tree has been planted.

There are significant ecological benefits associated with selective cutting. Pictured is an area with Ponderosa Pine trees that were selectively harvested.

History of the Conservation Movement

For much of human history, *nature* had been seen as a resource, one that could be controlled by the government and used for personal and economic gain. The idea was that plants only existed to feed animals and animals only existed to feed humans. The land itself had limited value only extending to the resources it could provide such as minerals and oil.

Throughout the 18th and 19th centuries social views started to change and scientific conservation principles were first practically applied to the forests of British India. The conservation ethic that began to evolve included three core principles: that human activity damaged the environment, that there was a civic duty to maintain the environment for future generations, and that scientific, empirically based methods should be applied to ensure this duty was carried out. Sir James Ranald Martin was prominent in promoting this ideology, publishing many medico-topographical reports that demonstrated the scale of damage wrought through large-scale deforestation and desiccation, and lobbying extensively for the institutionalization of forest conservation activities in British India through the establishment of Forest Departments.

The Madras Board of Revenue started local conservation efforts in 1842, headed by Alexander Gibson, a professional botanist who systematically adopted a forest conservation program based on scientific principles. This was the first case of state conservation management of forests in the world. Governor-General Lord Dalhousie introduced the first permanent and large-scale forest conservation program in the world in 1855, a model that soon spread to other colonies, as well the United States, where Yellowstone National Park was opened in 1872 as the world's first national park.

Rather than focusing on the economic or material benefits associated with nature, humans began to appreciate the value of nature itself and the need to protect pristine wilderness. By the middle of the 20th century countries such as the United States, Canada, and Britain understood this appreciation and instigated laws and legislation in order to ensure that the most fragile and beautiful environments would be protected for generations to come. Today with the help of NGO's, not-for profit organizations and governments world-wide there is a stronger movement taking place, with a deeper understanding of habitat conservation with the aim of protecting delicate habitats and preserving biodiversity on a global scale. The commitment and actions of small volunteering association in villages and towns, that endeavour to emulate the work done by well known Conservation Organisations, is paramount in ensuring generations that follow understand the importance of conserving natural resources. A village conservation group with the mission statement "We are committed to protecting and enhancing the natural environment in and around the adjoining villages of Ouston and Urpeth." may one day inspire a child who becomes the employee of a worldwide conservation organisation.

Values of Natural Habitat

The natural environment is a source for a wide range of resources that can be exploited for economic profit, for example timber is harvested from forests and clean water is obtained from natural streams. However, land development from anthropogenic economic growth often causes a decline in the ecological integrity of nearby natural habitat. For instance, this was an issue in the northern rocky mountains of the USA.

However, there is also economic value in conserving natural habitats. Financial profit can be made from tourist revenue, particularly in the tropics where species diversity is high. The cost of repairing damaged ecosystems is considered to be much higher than the cost of conserving natural ecosystems.

Measuring the worth of conserving different habitat areas is often criticized as being too utilitarian from a philosophical point of view.

Biodiversity

Habitat conservation is important in maintaining biodiversity, an essential part of global food security. There is evidence to support a trend of accelerating erosion of the genetic resources of agricultural plants and animals. An increase in genetic similarity of agricultural plants and animals means an increased risk of food loss from major epidemics. Wild species of agricultural plants have been found to be more resistant to disease, for example the wild corn species Teosinte is resistant to 4 corn diseases that affect human grown crops. A combination of seed banking and habitat conservation has been proposed to maintain plant diversity for food security purposes.

Classifying Environmental Values

Pearce and Moran outlined the following method for classifying environmental uses:

- Direct extractive uses: e.g. timber from forests, food from plants and animals
- Indirect uses: e.g. ecosystem services like flood control, pest control, erosion protection
- Optional uses: future possibilities e.g. unknown but potential use of plants in chemistry/medicine
- Non-use values:
    - Bequest value (benefit of an individual who knows that others may benefit from it in future)
    - Passive use value (sympathy for natural environment, enjoyment of the mere existence of a particular species)

Impacts

Natural Causes

Habitat loss and destruction can occur both naturally and through anthropogenic causes. Events leading to natural habitat loss include climate change, catastrophic events such as volcanic explosions and through the interactions of invasive and non-invasive species. Natural climate change, events have previously been the cause of many widespread and large scale losses in habitat. For example, some of the mass extinction events generally referred to as the “Big Five” have coincided with large scale such as the Earth entering an ice age, or alternate warming events. Other events in the big five also have their roots in natural causes, such as volcanic explosions and meteor collisions. The Chicxulub impact is one such example, which has previously caused widespread losses in habitat as the Earth either received less sunlight or grew colder, causing certain fauna and flora to flourish whilst others perished. Previously known warm areas in the tropics, the most sensitive habitats on Earth, grew colder, and areas such as Australia developed radically different flora and fauna to those seen today. The big five mass extinction events have also been linked to sea level changes, indicating that large scale marine species loss was strongly influenced by loss in marine habitats, particularly shelf habitats. Methane-driven oceanic eruptions have also been shown to have caused smaller mass extinction events.

Human Impacts

Humans have been the cause of many species’ extinction. Due to humans’ changing and modifying their environment, the habitat of other species often become altered or destroyed as a result of human actions. Even before the modern industrial era, humans were having widespread, and major effects on the environment. A good example of this is found in Aboriginal Australians and Australian megafauna. Aboriginal hunting practices, which included burning large sections of forest at a time, eventually altered and changed Australia’s vegetation so much that many herbivorous megafauna species were left with no habitat and were driven into extinction. Once herbivorous megafauna species became extinct, carnivorous megafauna species soon followed. In the recent past, humans have been responsible for causing more extinctions within a given period of time than ever before. Deforestation, pollution, anthropogenic climate change and human settlements have all been driving forces in altering or destroying habitats. The destruction of ecosystems such as rainforests has resulted in countless habitats being destroyed. These biodiversity hotspots are home to millions of habitat specialists, which do not exist beyond a tiny area. Once their habitat is destroyed, they cease to exist.This destruction has a follow-on effect, as species which coexist or depend upon the existence of other species also become extinct, eventually resulting in the collapse of an entire ecosystem. These time-delayed extinctions are referred to as the extinction debt, which is the result of destroying and fragmenting habitats. As a result of anthropogenic modification of the environment, the extinction rate has climbed to the point where the Earth is now within a sixth mass extinction event, as commonly agreed by biologists. This has been particularly evident, for example, in the rapid decline in the number of amphibian species worldwide.

Approaches and Methods of Habitat Conservation

Determining the size, type and location of habitat to conserve is a complex area of conservation biology. Although difficult to measure and predict, the conservation value of a habitat is often a reflection of the quality (e.g. species abundance and diversity), endangerment of encompassing ecosystems, and spatial distribution of that habitat.

Identifying Priority Habitats for Conservation

Habitat conservation is vital for protecting species and ecological processes. It is important to conserve and protect the space/ area in which that species occupies. Therefore, areas classified as 'biodiversity hotspots', or those in which a flagship, umbrella, or endangered species inhabits are often the habitats that are given precedence over others. Species that possess an elevated risk of extinction are given the highest priority and as a result of conserving their habitat, other species in that community are protected thus serving as an element of gap analysis. In the United States of America, a Habitat Conservation Plan (HCP) is often developed to conserve the environment in which a specific species inhabits. Under the U.S. Endangered Species Act (ESA) the habitat that requires protection in an HCP is referred to as the 'critical habitat'. Multiple-species HCPs are becoming more favourable than single-species HCPs as they can potentially protect an array of species before they warrant listing under the ESA, as well as being able to conserve broad ecosystem components and processes . As of January 2007, 484 HCPs were permitted across the United States, 40 of which covered 10 or more species.The San Diego Multiple Species Conservation Plan (MSCP) encompasses 85 species in a total area of 26,000-km2. Its aim is to protect the habitats of multiple species and overall biodiversity by minimizing development in sensitive areas. Hi

HCPs require clearly defined goals and objectives, efficient monitoring programs, as well as successful communication and collaboration with stakeholders and land owners in the area. Reserve design is also important and requires a high level of planning and management in order to achieve the goals of the HCP. Successful reserve design often takes the form of a hierarchical system with the most valued habitats requiring high protection being surrounded by buffer habitats that have a lower protection status. Like HCPs, hierarchical reserve design is a method most often used to protect a single species, and as a result habitat corridors are maintained, edge effects are reduced and a broader suite of species are protected.

How Much Habitat is Needed

A range of methods and models currently exist that can be used to determine how much habitat is to be conserved in order to sustain a viable population. Modelling tools often rely on the spatial scale of the area as an indicator of conservation value. There has been an increase in emphasis on conserving few large areas of habitat as opposed to many small areas. This idea is often referred to as the "single large or several small", SLOSS debate, and is a highly controversial area among conservation biologists and ecologists. The reasons behind the argument that "larger is better" include the reduction in the negative impacts of patch edge effects, the general idea that species richness increases with habitat area and the ability of larger habitats to support greater populations with lower extinction probabilities. Noss & Cooperrider support the "larger is better" claim and developed a model that implies areas of habitat less than 1000ha are "tiny" and of low conservation value. However, Shwartz suggests that although "larger is better", this does not imply that "small is bad". Shwartz argues that human induced habitat loss leaves no alternative to conserving small areas. Furthermore, he suggests many endangered species which are of high conservation value, may only be restricted to small isolated patches of habitat, and thus would be overlooked if larger areas were given a higher priority. The shift to conserving larger areas is somewhat justified in society by placing more value on larger vertebrate species, which naturally have larger habitat requirements.

Examples of Current Conservation Organizations

The Nature Conservancy

Since its formation in 1951 The Nature Conservancy has slowly developed into one of the world's largest conservation organizations. Currently operating in over 30 countries, across 5 continents world-wide, The Nature Conservancy aims to protect nature and its assets for future generations. The organization purchases land or accepts land donations with the intension of conserving its natural resources. In 1955 The Nature Conservancy purchased its first 60-acre plot near the New York/Connecticut border in the United States of America. Today the Conservancy has expanded to protect over 119 million acres of land, 5,000 river miles as well as participating in over 1000 marine protection programs across the globe . Since its beginnings The Nature Conservancy has understood the benefit in taking a scientific approach towards habitat conservation. For the last decade the organization has been using a collaborative, scientific method known as 'Conservation by Design'. By collecting and analyzing scientific data The Conservancy is able to holistically approach the protection of various ecosystems. This process determines the habitats that need protection, specific elements that should be conserved as well as monitoring progress so more efficient practices can be developed for the future.

The Nature Conservancy currently has a large number of diverse projects in operation. They work with countries around the world to protect forests, river systems, oceans, deserts and grasslands. In all cases the aim is to provide a sustainable environment for both the plant and animal life forms that depend on them as well as all future generations to come. turtles

World Wildlife Fund (WWF)

The World Wildlife Fund (WWF) was first formed in after a group of passionate conservationists signed what is now referred to as the Morges Manifesto. WWF is currently operating in over 100 countries across 5 continents with a current listing of over 5 million supporters. One of the first projects of WWF was assisting in the creation of the Charles Darwin Research Foundation which aided in the protection of diverse range of unique species existing on the Galápagos' Islands, Ecuador. It was also a WWF grant that helped with the formation of the College of African Wildlife Management in Tanzania which today focuses on teaching a wide range of protected area management skills in areas such as ecology, range management and law enforcement. The WWF has since gone on to aid in the protection of land in Spain, creating the Coto Doñana National Park in order to conserve migratory birds and The Democratic Republic of Congo, home to the world's largest protected wetlands. The WWF also initiated a debt-for-nature concept which allows the country to put funds normally allocated to paying off national debt, into conservation programs that protect its natural landscapes. Countries currently participating include Madagascar, the first country to participate which since 1989 has generated over $US50 million towards preservation, Bolivia, Costa Rica, Ecuador, Gabon, the Philippines and Zambia.

Rare Conservation

Rare has been in operation since 1973 with current global partners in over 50 countries and offices in the United States of America, Mexico, the Philippines, China and Indonesia. Rare focuses on the human activity that threatens biodiversity and habitats such as overfishing and unsustainable agriculture. By engaging local communities and changing behaviour Rare has been able to launch campaigns to protect areas in most need of conservation. The key aspect of Rare's methodology is their "Pride Campaign's". For example, in the Andes in South America, Rare has partnered with 11 different sites with the intention of creating incentives to develop watershed protection practices. In the Southeast Asia's "coral triangle" Rare is training fishers in local communities to better manage the areas around the coral reefs in order to lessen human impact. Such programs last for three years with the aim of changing community attitudes so as to conserve fragile habitats and provide ecological protection for years to come.

WWF Netherlands

WWF Netherlands, along with ARK Nature, Wild Wonders of Europe and Conservation Capital have started the Rewilding Europe project. This project intents to rewild several areas in Europe.

Habitat Conservation Plan

A Habitat Conservation Plan (HCP) is a required part of an application for an Incidental Take Permit, a permit issued under the United States Endangered Species Act (ESA) to private entities undertaking projects that might result in the destruction of an endangered or threatened species. It is a planning document that ensures that the anticipated take of a listed species will be minimized or mitigated by conserving the habitat upon which the species depend, thereby contributing to the recovery of the species as a whole.

Mature redwood trees in Gilham's Heath Plantation. Incidental take permits and HCPs are required for deforestation activities that have the potential to result in an incidental take of federally listed wildlife.

Background

The importance of preserving rare species was legally recognized in 1973 when the Endangered Species Act (ESA) was signed into federal law. The purpose of the ESA is not only to protect species that have been listed as threatened or endangered, but also to conserve the ecosystems upon which those species depend. In aiming to protect species in danger of becoming extinct, the ESA prohibits actions that have the potential to result in a "taking" of any listed species. The term "take" under the ESA refers to any attempt or action involving the harassment, harm, pursuit, hunting, shooting, wounding, killing, trapping, capturing, or collecting of any listed species. Under this definition, the alteration of habitat that results in injury to, or death of, any listed species by preventing essential behavior (such as breeding, feeding or sheltering) is considered unlawful "harm". The United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) are the lead agencies tasked with the implementation of the ESA and are therefore responsible for regulating prohibited and allowable activities. While the primary objective of the ESA is the protection of endangered species, and the take of such species is considered unlawful, the ESA is not absolute. In 1982, amendments were made to the 1973 ESA which authorize the Secretary of the Interior and the Secretary of Commerce to allow the take of federally listed species (Endangered Species Act, Section 10a(1)(B)). When non-federal activities that would otherwise be legal have the potential to result in the take of a listed species for example, they may be allowed under an Incidental Take Permit, obtained through the USFWS.

To mitigate the take of listed species, Section 10 of the ESA requires that parties wishing to obtain an Incidental Take Permit must submit a conservation plan, hereafter referred to as a “Habitat Conservation Plan” or “HCP,” with their application.

Phases of Developing a HCP

I. Pre-application Process

Determine Permit Applicant(s)/HCP Preparer(s)

In determining the party to prepare a HCP and application for an Incidental Take Permit, two primary factors must be considered; first, the party must be capable of overseeing the implementation of the HCP once approved and second, the party must be capable of funding the implementation of the HCP. Beyond these requirements, parties can vary based on the scope of the proposed action. For example, a single landowner may be the sole preparer of a HCP if they intend to obtain an Incidental Take Permit for an action on their own property and they are the only interested party. For large-scale projects such as those covering a region of land rather than a single property, or those with multiple interested parties rather than a single landowner, the permittee may be a group such as a local or governmental agency.

Determine the Members of the Steering Committee (optional)

For large-scale projects, applicants have the option of forming a steering committee composed of persons, such as stakeholders, with an interest in the HCP planning area or affected species. The purpose of a steering committee is to provide the applicant with direction, guidance, advice, and assistance in developing the HCP. Although the development and participation of a steering committee is not a requirement in preparing a HCP, it can be found valuable in facilitating the HCP process when multiple groups with differing interests and opinions regarding the project are involved.

Consultation with the U.S. Fish and Wildlife Service and National Marine Fisheries Service

After the applicant and steering committee members have been determined, consultation with USFWS and NMFS is recommended to ensure that responsible parties have a thorough understanding of requirements and resources available for the development phase of the HCP.

II. Development Process

Generate a Species list

Once the applicant has decided to initiate the development of a HCP, they must identify the species of concern that the HCP will be developed for. All federally listed animal species that have the potential to be impacted by the proposed action/project must be included in this list. Additional unlisted species may also be considered in the HCP. Including these additional species may be beneficial in some cases, if the proposed action has the potential to impact species that are not federally listed at the time the HCP is being developed but are anticipated to be listed within the active duration of the permit; in which case, the HCP would need to be revised to include the newly listed species and may further delay the proposed action.

Habitat-based Approach

An alternative method to developing a HCP for target species of concern is to develop a HCP for a particular habitat type. Under this approach, a specific habitat type found within the HCP area is selected as the focus of the HCP by the permittee and USFWS/NMFS based on the species known to use the habitat. The habitat-based HCP must consider all sensitive species known to use the particular habitat type and all of their habitat-related needs. All species considered within the habitat-based HCP may be included under the Incidental Take Permit. The benefit of developing a habitat-based HCP rather than a species-based HCP is that, if prepared properly, a single HCP would theoretically benefit multiple species or an entire ecosystem rather than only protecting the species listed under the ESA.

Define Geographic Boundaries

Once the target species or habitat type to be considered in the HCP have been identified, the geographic boundaries of the planning area need to be established. It is important to be precise when defining the land area to which the HCP will apply, with regards to impacts associated with the proposed action, to circumvent potential problems in later phases of the development process. The geographic boundaries of the HCP should encompass all areas that will be directly impacted by the proposed action and any areas where an incidental take has the potential to occur as a result of the proposed action.

Gather Biological Data

After delineating the boundaries of the HCP area and the species within that area to be included in the HCP, current biological information for each of those species must be obtained. Data pertaining to the species' ecology, geographical distribution, and occurrence is required and may be available from existing sources. Guidance for locating this information is provided by USFWS and NMFS. If existing information is not available or sufficient for the requirements of the HCP, biological studies must be completed to supplement this requirement. If a biological study is determined necessary, USFWS and NMFS can suggest appropriate methods based on the species of concern.

Discuss Proposed Activities

After sufficient biological information has been collected for each of the species included in the HCP, the applicant must provide a discussion of all proposed activities that have a potential to result in an incidental take of said species. This portion of the HCP is where the applicant provides a detailed comprehensive description of the proposed action/project, which can vary in depth based on the scale of the project and HCP area. For the purpose of long-term planning, applicants are encouraged to include any actions that they have control over that are reasonably foreseeable to occur during the active permit period.

Low-Effect HCP

Due to the varying degrees by which a species may be impacted from a project, the Low-Effect HCP category is established to distinguish projects that are expected to have "minor or negligible effects on federally listed, proposed, or candidate species and their habitats or environmental values or resources". Low-Effect HCPs have a simplified and shortened application/approval process compared to a regular HCP. USFWS and NMFS will review the HCP and determine if it may be considered within the low-effect category or not.

Determine Significance of Anticipated Incidental take

In requesting a permit that will authorize the incidental take of a listed species, the applicant must determine the extent of the potential take. To do this, the methods for calculating incidental take must be established. First, the number of individuals of each species, or number of acres of specific habitat, of concern that occur within the geographic boundaries of the HCP area must be determined. Subsequently, incidental take may be calculated based on the number of animals expected to be "killed, harmed, or harassed" as a result of the proposed action/project. If the applicant is incapable of determining the number of individuals/acres that occur in the area or the number that are expected to be impacted, incidental take may be calculated based on the acres of habitat anticipated to be affected by the proposed project. Once the number of individual species or acres of habitat are confirmed, the probability that proposed activities will result in the take of a species must be evaluated.

Develop a Mitigation Program

After an allowable level of take is determined, the applicant may begin to prepare the mitigation program. Because projects requiring an Incidental Take Permit are so diverse, applicable mitigation measures should be equally diverse; therefore, limits and rules are not established for this process.

Common mitigation measures often include the following:

1. Avoid the impact
2. Minimize the impact

3. Rectify the impact
4. Reduce/eliminate the impact over time
5. Compensate for the impact

The general goals of a mitigation program are to offset the immediate incidental take by either positively contributing to the species as a whole or to the objectives of the recovery plan designed for that species by USFWS.

Mitigating for Habitat Loss

Most projects requiring an Incidental Take Permit involve impacts to, or losses of, habitat. Mitigating for habitat loss requires either the replacement or protection of habitat within the HCP area or at another location. This may be accomplished through a variety of methods including:

1. Acquiring existing habitat;
2. Employing conservation easements to protect existing habitat;
3. Improving or restoring degraded habitat;
4. Management of habitats to achieve specific conditions; or
5. Creating new habitat.

Examples of Habitat Mitigation Programs

- Habitat Banking- used to mitigate for habitat loss by designating and protecting land through conservation easements within the HCP area during the design phase of the project.
- Mitigation Credit System- uses protected (banked) lands as credits available for purchase. This system enables parties capable of protecting large areas to receive monetary gain from other parties requiring habitat mitigation. Likewise, this system is beneficial for parties not capable of protecting sufficient habitat within their HCP area by enabling them to quickly purchase credits that satisfy their mitigation requirements.
- Mitigation Fund- involves making monetary contributions of an established amount to an account that is used as a habitat acquisition fund.

In general, it is recommended that habitat mitigation be located reasonably close to the location of habitat impacted by the proposed action/project, provide similar habitat types, and support the same species expected to be impacted by the proposed action/project; however, these attributes vary from project to project. It is typically expected that the extent of mitigation should mirror the proposed impact. For example, if a project will result in permanent destruction of habitat, mitigation measures will likely require either the creation of new habitat or the protection of habitat, and mitigated habitat should be permanently protected. Similarly, mitigation for Low-Effect HCPs and small projects may involve a payment to a fund or purchasing mitigation credits.

Develop a Monitoring Program

To ensure the effectiveness of the HCP, it is essential for monitoring to be implemented throughout the development of the action/project and following its completion. HCP monitoring programs are recommended to incorporate the following features:

1. Establish specific objectives for monitoring;
2. Clarify the focus of the monitoring program (specific species, specific habitat types, etc.);
3. Specify the characteristics to be monitored and methods to be employed for data collection;
4. Establish a monitoring schedule that determines the frequency and duration by which monitoring will take place; and
5. Discuss the process by which data will be analyzed (who will perform the analysis, how will data be evaluated etc.)

Identify/Provide Funding

Every HCP is required to identify the funding that will be provided for its implementation. Sufficient funding must be provided for all proposed activities, including those relating to any necessary surveys, monitoring programs, mitigation programs, and construction of the proposed project. Funding amounts and contributors will vary based on the scale of the proposed project. Projects impacting large areas of land, for example, typically require funding from multiple sources. The HCP must identify all financial contributors and planned allocation of funds.

Analyze Alternatives

Permittees are required to include a discussion of other options, besides the proposed action/project, that would not result in the proposed taking. It is common for this discussion to include two alternatives; one being a “no action” alternative under which a permit would not be issued and the proposed project would not be developed, the other being a specific project alternative that would result in a reduced impact/take than the proposed project. All alternatives considered during the permit application and HCP development process must be included. Following the discussion of possible alternatives, the permittee must explain why each of the alternatives was deemed unsuitable and not chosen as the proposed project.

Consider Unforeseen Circumstances

In the development phase of the HCP process, applicants are encouraged to consider elements that have the potential to change over time. Given the unpredictable nature of the future, it would be impossible to prepare for every situation that has the potential to arise. For this reason, an assurance policy is incorporated in the HCP process.

No Surprises Policy

The No Surprises Policy is designed to protect Incidental Take Permit-holders from having to make future revisions to their approved plan due to unforeseen circumstances. This means that once a permittee has prepared a HCP deemed adequate by USFWS/NMFS, has been issued an Incidental Take Permit, and is successfully implementing the approved HCP, USFWS and NMFS will not require revisions be made to the accepted plan (such as additional mitigation) if unexpected circumstances arise.

III. Approval/Implementation Process

Review of HCP Required Content

Habitat conservation plans may vary to some degree in content; however, there are certain elements that are universally required. Inclusion of the following is required of every HCP:

1. Analysis of impacts that have the potential to occur as a result of the proposed taking of a threatened or endangered species;
2. Steps to be taken by the permit-holder to "...monitor, minimize, and mitigate for such impacts;"
3. Sufficient funding for implementing these steps;
4. A plan of action for handling any unanticipated circumstances;
5. A discussion of potential alternative actions taken into consideration by the permittee that would not result in the take of a listed species, and basis for not choosing these alternatives

Interpret Significance of Anticipated Incidental Take

Once the degree of incidental take is calculated based on the factors discussed above, it is up to UFSWS and NMFS to determine if the proposed incidental take should be authorized. When evaluating the estimated level of take, the following criteria (outlined in

ESA section 10(a)(2)(B)) are employed to determine if the incidental take is acceptable:

1. The proposed "take" of a species would be incidental (it would be the result of, rather than the purpose for, an otherwise legal action).
2. The party applying for the Incidental Take Permit would develop a mitigation program capable of minimizing and mitigating the impacts of the proposed take to the maximum extent practicable.
3. The party applying for the Incidental Take Permit would ensure that sufficient funding for the HCP will be provided.
4. The proposed take would not substantially diminish the ability of the species to recover and survive in the wild.

The HCP must be consistent with these criteria before being approved for an Incidental Take Permit. If the estimated level of take is determined to exceed allowable amounts by USFWS and NMFS, the HCP must be revised to further reduce the potential for take. This is often most easily achieved by increasing the amount of land that will remain undisturbed.

Implementing Agreement

Implementing Agreements are made between the permittee and USFWS/NMFS to assure that the permittee will follow through on their obligation to implement the mitigation program identified by the HCP. They are individually tailored for HCPs and include all applicable permit conditions and requirements of the parties involved. They are signed by all parties, thereby establishing the intent of adhering to the terms identified by the HCP. Implementing Agreements are not required of every HCP; they are most often utilized for large-scale projects involving multiple parties and are rarely used for Low-Effect HCPs.

Progress and Momentum of the Habitat Conservation Plan

Since its inclusion in the ESA in 1982, the process of habitat conservation planning has been steadily gaining momentum. Between 1982 and 1992, the USFWS had approved a total of 14 HCPs and had issued 14 incidental take permits. As of December 2005, over 430 HCPs had been officially approved, varying in size and scope, with many more in the development phase.

Additional Conservation Agreements

Congress addressed taking restrictions in the 1990s by creating additional agreements to assist in species recovery. Instituted by USFWS and NMFS, safe harbor agreements and candidate conservation agreements are incentive-driven and voluntary. Because of their greater flexibility for property owners, these agreements are likely to become more popular.

Safe Harbor Agreement (SHA)

Similar to HCPs, Safe Harbor Agreements (SHAs) are voluntary agreements between non-federal landowners and USFWS or NMFS. SHAs encourage landowners to create, enhance, or maintain habitat for threatened or endangered species on their property. Prior to the agreement, landowners and agencies establish baseline conditions for the habitat to be capable of supporting the species. The agency provides assurances to the landowners and guarantees that, if the conditions of the SHA are met, the landowners will not be subject to any additional requirements than previously agreed upon. Incidental take by the landowner is authorized as long as the species does not fall below the agreed-upon baseline conditions. Landowners are not bound indefinitely to SHAs and can either renew or let the agreements expire. This allows landowners to freely manage their property, including development, as long as they maintain baseline conditions. As of 2009, USFWS had entered into over 70 SHAs.

Candidate Conservation Agreement (CCA)

Similar to SHAs, Candidate Conservation Agreements (CCAs) are voluntary agreements between private or public parties (including landowners, state, local, and federal agencies) and USFWS or NMFS. CCAs aim to protect candidate species that are in decline and vulnerable to becoming endangered if measures are not taken to protect their habitat. CCAs encourage landowners to create, enhance, or maintain habitat for these species on their property. CCAs do not provide assurances for landowners or authorize incidental take.

Candidate Conservation Agreement with Assurances (CCAA)

Candidate Conservation Agreements with Assurances (CCAAs) are voluntary agreements between non-federal landowners and USFWS or NMFS. CCAAs provide assurances and authorize a specific allotment of incidental take by the landowner.

Flexible Scope of Habitat Conservation Plans

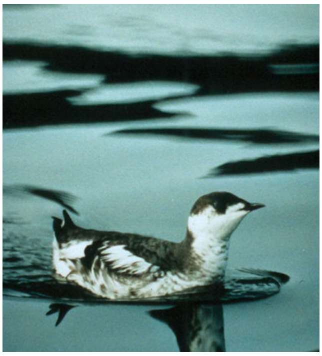
Example: Small-scale HCP

HCPs are designed to be flexible to accommodate a range of projects that vary greatly in size and scope, from single-property developments to hundreds of thousands of acres involving multiple parties. An HCP created for construction of a single-family home on a 0.44-acre lot in Scotts Valley, California proposed mitigation and minimization measures aimed at the endangered Mount Hermon June beetle (Polyphylla barbata) and Ben Lomond spineflower (Chorizanthe pungens var. hartwegiana). Measures for the

5,856 ft^2 project included no development on the land where the spineflower is located and elimination of non-native plants growth on the land to prevent competition. Measures to protect the beetle took into account breeding and flight activities and proposed landscaping to promote the beetle's habitat.

Example: Large-scale HCP

Alternatively, the large-scale HCP created for 211,700 acres of the Headwaters Forest in Northern California near Eureka dealt with the largest old-growth redwood ecosystem in the United States. The threatened northern spotted owl (*Strix occidentalis caurina*) and marbled murrelet (*Brachyramphus marmoratus*) rely on the large redwoods for nesting as well as the threatened coho salmon (*Oncorhynchus kisutch*), who are dependent on the habitat's stream for spawning. Pacific Lumber Company, Scotia Pacific Holding Company, and Salmon Creek Company (collectively known as PALCO) created an HCP in 1998 that addressed road building and timber harvest as the greatest threats to the species. The resulting extensive mitigation and monitoring measures provided strict restrictions for land use, including buffers and operational limitations in riparian areas with active murrelet nests. The HCP also maintained that northern spotted owl nesting, roosting, and foraging habitat be provided and maintained.



Threatened marbled murrelet (*Brachyramphus marmoratus*)

Threatened northern spotted owl (*Strix occidentalis caurina*). A project, such as planned logging, that might lead to habitat destruction of the northern spotted owl would require submitting a Habitat Conservation Plan as part of its Incidental Take Permit.

Strengths and Weaknesses of HCPs

The environmental community and landowners take different stands on HCPs.

Strengths:

- Flexible to accommodate a wide range of projects that vary greatly in size and scope.
- Forces consideration of species by all parties.
- Reduced uncertainty for landowners.

Weaknesses:

- Inflexible with regards to changing knowledge relating to species and habitat.
- The “No Surprises Policy” has been highly controversial with critics arguing that it burdens the agencies, rather than landowners, with additional financial and mitigation responsibilities if unforeseen circumstances arise.
- HCPs are viewed as having weak and insufficient monitoring plans. Additionally, the parties responsible for monitoring HCPs are not regulated in a systematic manner due to private funding.
- Criticism over scientific standards and limited credible scientific data.
- Agencies have interpreted the role of HCPs under section 10(a) of the ESA as a means to contribute to survival of species but not as a recovery tool. The Habitat Conservation Planning Handbook is inconsistent with this stand and states that “...contribution to recovery is often an integral product of an HCP...” and in general, conservation plans that are not consistent with recovery plan objectives should be discouraged”.

The Role of HCPs in Court (Previous Cases/Standing)

Endangered mission blue butterfly (*Icaricia icarioides missionensis*), protected by the San Bruno Mountain HCP.

Endangered Alabama beach mouse (*Peromyscus polionotus ammobates*) at issue in *Sierra Club v. Babbitt*, in which it was threatened by beachfront condominium development.

The number of approved HCPs has grown since the first HCP was created in 1983 for San Bruno Mountain in San Mateo County, California. Congress wanted the San Bruno Mountain HCP to serve as a model for future HCPs in that it was created from "an independent exhaustive biological study" and that it considered the habitat of the mission blue butterfly (Aricia icarioides missionensis) "to allow for enhancement of the survival of the species". This model has drawn concern because it focuses more on species survival, while the intent of HCPs is to aid species recovery; and has resulted in HCPs being frequently challenged in court. In *Sierra Club v. Babbitt, 15 F. Supp. 2D 1274 (S.D.Ala.1998)*, the Plaintiff challenged the USFWS issuance of Incidental Take Permits to the developers of two beachfront condominium projects based on the HCPs submitted as part of the application process. The Plaintiffs argued that the HCPs created for the endangered Alabama beach mouse (*Peromyscus polionotus ammobates*) did not fulfill the requirements of ESA section 10(a)(2)(B) requiring the development of "a mitigation program that will minimize and mitigate the impacts of the proposed taking to the maximum extent practicable". Additionally, the Plaintiff argued that there was insufficient biological data for the Alabama beach mouse species in the HCP, including population abundance, to determine allowable levels of take. The Court found for the Plaintiffs and remanded the decision to issue the Incidental Take Permits to USFWS.

Habitat Cascade

A habitat cascade is a common type of a facilitation cascade. where "indirect positive effects on focal organisms are mediated by successive formation or modification of biogenic habitat".

A habitat cascade is composed of at least three organisms: a primary habitat former or modifier; a secondary habitat former or modifier; and a focal organism that utilizes the secondary habitat former or modifier. For example, primary habitat forming trees can provide habitat for secondary habitat forming epiphytes, lianas, or vines that again can provide habitat to focal organisms like insects and birds.

The primary vs. secondary habitat formers are sometimes referred to as ultimate vs. proximate habitat formers, basal vs. intermediate habitat formers, primary vs. secondary ecosystem engineers, primary vs. secondary foundation species, basibionts vs. epibionts, basizoids (if animal) or basiphytes (if plant) vs. epizooids (if animal) or epiphytes (if plant), or hosts vs. structural parasites. Focal organisms have been referred to as clients, end-users, habitat-users, inhabitants or hyperepibionts

Secondary habitat formers are typically attached to, entangled around, or embedded within the primary habitat former. Habitat cascades are strongest when the secondary habitat former is more effective than the primary habitat former at allowing focal organisms to avoid stress and enemies, and find resources and other facilitators.

Habitat cascades promote increased biodiversity in ecosystems dominated by large and long-lived sessile or slow-moving structural organisms. For example, habitat cascades have been documented in tropical forests, temperate forests, salt marshes, coral reefs, seagrass beds, mangrove stands, polychaete gardens, seaweed covered rocky coasts and mollusc reefs

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6

Endangered Species: An Overview

Species that have been classified by the international union for conservation of nature for having the highest probability of becoming extinct is known as endangered species. The various endangered species discussed in this section are passenger pigeons, Asiatic lions and snow leopards. This chapter is an overview of the subject matter incorporating all the major aspects of endangered species.

Endangered Species

An Endangered (EN) species is a species which has been categorized by the International Union for Conservation of Nature (IUCN) Red List as likely to become extinct. "Endangered" is the second most severe conservation status for wild populations in the IUCN's schema after Critically Endangered (CR).

In 2012, the IUCN Red List featured 3079 animal and 2655 plant species as endangered (EN) worldwide. The figures for 1998 were, respectively, 1102 and 1197.

Many nations have laws that protect conservation-reliant species: for example, forbidding hunting, restricting land development or creating preserves. Population numbers, trends and species' conservation status can be found in the lists of organisms by population.

Conservation Status

The conservation status of a species indicates the likelihood that it will become extinct. Many factors are considered when assessing the conservation status of a species; e.g., such statistics as the number remaining, the overall increase or decrease in the population over time, breeding success rates, or known threats. The IUCN Red List of Threatened Species is the best-known worldwide conservation status listing and ranking system.

Over 40% of the world's species are estimated to be at risk of extinction. Internationally, 199 countries have signed an accord to create Biodiversity Action Plans that will protect endangered and other threatened species. In the United States, such plans are usually called Species Recovery Plans.

IUCN Red List

Though labelled a list, the IUCN Red List is a system of assessing the global conservation status of species that includes "Data Deficient" (DD) species – species for which more data and assessment is required before their status may be determined – as well species comprehensively assessed by the IUCN's species assessment process. Those species of "Near Threatened" (NT) and "Least Concern" (LC) status have been assessed and found to have relatively robust and healthy populations, though these may be in decline. Unlike their more general use elsewhere, the List uses the terms "endangered species" and "threatened species" with particular meanings: "Endangered" (EN) species lie between "Vulnerable" (VU) and "Critically Endangered" (CR) species, while "Threatened" species are those species determined to be Vulnerable, Endangered or Critically Endangered.

The Siberian tiger is an Endangered (EN) tiger subspecies. Three tiger subspecies are already extinct (see List of carnivorans by population).

Blue-throated macaw, an endangered species

Brown spider monkey, an endangered species

The IUCN categories, with examples of animals classified by them, include:

Extinct (EX)

- Examples: aurochs
- Bali tiger
- blackfin cisco
- Caribbean monk seal
- Carolina parakeet
- Caspian tiger
- dodo
- dusky seaside sparrow
- eastern cougar
- golden toad
- great auk
- Japanese sea lion
- Javan tiger
- Labrador duck
- passenger pigeon
- Schomburgk's deer
- Steller's sea cow
- thylacine
- toolache wallaby
- western black rhinoceros
- California Grizzly Bear

Criteria for 'Endangered (EN)'

A) Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥ 70% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:

   1. direct observation
   2. an index of abundance appropriate for the taxon
   3. a decline in area of occupancy, extent of occurrence and/or quality of habitat
   4. actual or potential levels of exploitation
   5. the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of ≥ 50% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.
3. A population size reduction of ≥ 50%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
4. An observed, estimated, inferred, projected or suspected population size reduction of ≥ 50% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B) Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 5,000 km^2, and estimates indicating at least two of a-c:
   1. Severely fragmented or known to exist at no more than five locations.
   2. Continuing decline, inferred, observed or projected, in any of the following:
      1. extent of occurrence
      2. area of occupancy
      3. area, extent and/or quality of habitat
      4. number of locations or subpopulations
      5. number of mature individuals

3. Extreme fluctuations in any of the following:

    1. extent of occurrence
    2. area of occupancy
    3. number of locations or subpopulations
    4. number of mature individuals

2. Area of occupancy estimated to be less than 500 km^2, and estimates indicating at least two of a-c:

    1. Severely fragmented or known to exist at no more than five locations.
    2. Continuing decline, inferred, observed or projected, in any of the following:

        1. extent of occurrence
        2. area of occupancy
        3. area, extent and/or quality of habitat
        4. number of locations or subpopulations
        5. number of mature individuals

    3. Extreme fluctuations in any of the following:

        1. extent of occurrence
        2. area of occupancy
        3. number of locations or subpopulations
        4. number of mature individuals

C) Population estimated to number fewer than 2,500 mature individuals and either:

1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, (up to a maximum of 100 years in the future) OR
2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the follow (a-b):

    1. Population structure in the form of one of the following:

        1. no subpopulation estimated to contain more than 250 mature individuals, OR

        2. at least 95% of mature individuals in one subpopulation

    2. Extreme fluctuations in number of mature individuals

D) Population size estimated to number fewer than 250 mature individuals.

E) Quantitative analysis showing the probability of extinction in the wild is at least 20% within 20 years or five generations, whichever is the longer (up to a maximum of 100 years).

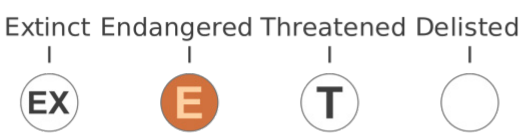
1. Near-critically endangered.
2. Particularly sensitive to poaching levels.
3. Near-endangered due to poaching.
4. May vary according to levels of tourism.
5. Varies according to female populations.

Endangered Species in the United States

There is data from the United States that shows a correlation between human populations and threatened and endangered species. Using species data from the Database on the Economics and Management of Endangered Species (DEMES) database and the period that the Endangered Species Act (ESA) has been in existence, 1970 to 1997, a table was created that suggests a positive relationship between human activity and species endangerment. As early as the 1800s, humans began noticing the decline of certain species of animals in their usual habitats. An example is the whooping crane. Once abundant from Canada to Mexico, it was estimated in 1941 that only 16 birds remained in the wild. Another early example of mankind noticing the extinction of species was the introduction of "kudzu" in the southern United States. This fast-growing plant took over the south, growing on plants and trees and squelching the life out of them.How Many Endangered Species are there in US?

According to information of IUCN red list there are around 391 endangered species occur in United States.

Endangered Species Act



"Endangered" in relation to "threatened" under the ESA.

Under the Endangered Species Act in the United States, species may be listed as "endangered" or "threatened". The Salt Creek tiger beetle (*Cicindela nevadica lin-*

colniana) is an example of an endangered subspecies protected under the ESA. The US Fish and Wildlife Service as well as the National Marine Fisheries Service are held responsible for classifying and protecting endangered species, and adding a particular species to the list can be a long, controversial process (Wilcove & Master, 2008, p. 414).

Some endangered species laws are controversial. Typical areas of controversy include: criteria for placing a species on the endangered species list and criteria for removing a species from the list once its population has recovered; whether restrictions on land development constitute a “taking” of land by the government; the related question of whether private landowners should be compensated for the loss of uses of their lands; and obtaining reasonable exceptions to protection laws. Also lobbying from hunters and various industries like the petroleum industry, construction industry, and logging, has been an obstacle in establishing endangered species laws.

The Bush administration lifted a policy that required federal officials to consult a wildlife expert before taking actions that could damage endangered species. Under the Obama administration, this policy has been reinstated.

Being listed as an endangered species can have negative effect since it could make a species more desirable for collectors and poachers. This effect is potentially reducible, such as in China where commercially farmed turtles may be reducing some of the pressure to poach endangered species.

Another problem with the listing species is its effect of inciting the use of the “shoot, shovel, and shut-up” method of clearing endangered species from an area of land. Some landowners currently may perceive a diminution in value for their land after finding an endangered animal on it. They have allegedly opted to silently kill and bury the animals or destroy habitat, thus removing the problem from their land, but at the same time further reducing the population of an endangered species. The effectiveness of the Endangered Species Act – which coined the term «endangered species» – has been questioned by business advocacy groups and their publications but is nevertheless widely recognized by wildlife scientists who work with the species as an effective recovery tool. Nineteen species have been delisted and recovered and 93% of listed species in the northeastern United States have a recovering or stable population.

Currently, 1,556 known species in the world have been identified as near extinction or endangered and are under protection by government law. This approximation, however, does not take into consideration the number of species threatened with endangerment that are not included under the protection of such laws as the Endangered Species Act. According to NatureServe’s global conservation status, approximately thirteen percent of vertebrates (excluding marine fish), seventeen percent of vascular plants, and six to eighteen percent of fungi are considered imperiled. Thus, in total, between seven and eighteen percent of the United States’ known animals, fungi and plants are near extinction. This total is substantially more than the number of species protected in the United States under the Endangered Species Act.

Bald eagle

American bison

Ever since mankind began hunting to preserve itself, over-hunting and fishing has been a large and dangerous problem. Of all the species who became extinct due to interference from mankind, the dodo, passenger pigeon, great auk, Tasmanian tiger and Steller's sea cow are some of the more well known examples; with the bald eagle, grizzly bear, American bison, Eastern timber wolf and sea turtle having been hunted to near-extinction. Many began as food sources seen as necessary for survival but became the target of sport. However, due to major efforts to prevent extinction, the bald eagle, or *Haliaeetus leucocephalus* is now under the category of Least Concern on the red list. A present-day example of the over-hunting of a species can be seen in the oceans as populations of certain whales have been greatly reduced. Large whales like the blue whale, bowhead whale, finback whale, gray whale, sperm whale and humpback whale are some of the eight whales which are currently still included on the Endangered Species List. Actions have been taken to attempt reduction in whaling and increase population sizes, including prohibiting all whaling in United States waters, the formation of the CITES treaty which protects all whales, along with the formation of the International Whaling Commission (IWC). But even though all of these movements have been put in place, countries such as Japan continue to hunt and harvest whales under the claim of "scientific purposes". Over-hunting, climatic change and habitat loss leads in landing species in endangered species list and could mean that extinction rates could increase to a large extent in the future.

Invasive Species

The introduction of non-indigenous species to an area can disrupt the ecosystem to such an extent that native species become endangered. Such introductions may be termed alien or invasive species. In some cases the invasive species compete with the native species for food or prey on the natives. In other cases a stable ecological balance may be upset by predation or other causes leading to unexpected species decline. New species may also carry diseases to which the native species have no resistance.

Conservation

The dhole, Asia's most endangered top predator, is on the edge of extinction.

Captive Breeding

Captive breeding is the process of breeding rare or endangered species in human controlled environments with restricted settings, such as wildlife reserves, zoos and other conservation facilities. Captive breeding is meant to save species from extinction and so stabilize the population of the species that it will not disappear.

This technique has worked for many species for some time, with probably the oldest known such instances of captive mating being attributed to menageries of European and Asian rulers, an example being the Père David's deer. However, captive breeding techniques are usually difficult to implement for such highly mobile species as some migratory birds (e.g. cranes) and fishes (e.g. hilsa). Additionally, if the captive breeding population is too small, then inbreeding may occur due to a reduced gene pool and reduce immunity.

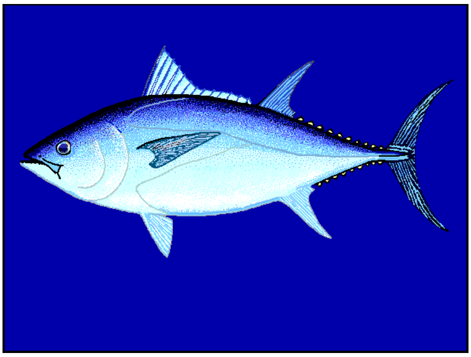
In 1981, the Association of Zoos and Aquariums (AZA) created a Species Survival Plan (SSP) in order to help preserve specific endangered and threatened species through captive breeding. With over 450 SSP Plans, there are a number of endangered species that are covered by the AZA with plans to cover population management goals and recommendations for breeding for a diverse and healthy population, created by Taxon Advisory Groups. These programs are commonly created as a last resort effort. SSP

Programs regularly participate in species recovery, veterinary care for wildlife disease outbreaks, and a number of other wildlife conservation efforts. The AZA's Species Survival Plan also has breeding and transfer programs, both within and outside of AZA - certified zoos and aquariums. Some animals that are part of SSP programs are giant pandas, lowland gorillas, and California condors.

Private Farming

Black rhino

Whereas poaching substantially reduces endangered animal populations, legal, for-profit, private farming does the opposite. It has substantially increased the populations of the southern black rhinoceros and southern white rhinoceros. Dr Richard Emslie, a scientific officer at the IUCN, said of such programs, "Effective law enforcement has become much easier now that the animals are largely privately owned... We have been able to bring local communities into the conservation programmes. There are increasingly strong economic incentives attached to looking after rhinos rather than simply poaching: from Eco-tourism or selling them on for a profit. So many owners are keeping them secure. The private sector has been key to helping our work."



Southern bluefin tuna

Conservation experts view the effect of China's turtle farming on the wild turtle populations of China and South-Eastern Asia – many of which are endangered – as "poorly understood". Although they commend the gradual replacement of turtles caught wild with farm-raised turtles in the marketplace – the percentage of farm-raised individuals in the "visible" trade grew from around 30% in 2000 to around 70% in 2007 – they worry that many wild animals are caught to provide farmers with breeding stock. The conservation expert Peter Paul van Dijk noted that turtle farmers often believe that animals caught wild are superior breeding stock. Turtle farmers may, therefore, seek and catch the last remaining wild specimens of some endangered turtle species.

In 2009, researchers in Australia managed to coax southern bluefin tuna to breed in landlocked tanks, raising the possibility that fish farming may be able to save the species from overfishing.

Countries with Endangered Animals

Around the world hundreds of thousands of species are lost to extinction, many of them only discovered as remains, after they are gone. Thus, not only biological variability, but also genetic diversity, and perhaps sources of livelihood for future generations are lost. Endangered species are species that may become extinct in the near future. Throughout history millions of species have disappeared, due to natural processes. In the past 300 years, however, humans have increased the rate of extinction.

For some plant and animal species, living seems to be a daily hazard. And humans seem to pose the biggest threat. Ecological disasters, hunting/poaching, deforestation and other consequences of human action causes damage to the food chain, breeding grounds, and habitat.

Various Endangered Species

Passenger Pigeon

The passenger pigeon or wild pigeon (*Ectopistes migratorius*) is an extinct species of pigeon that was endemic to North America. Its common name is derived from the French word *passager*, meaning "passing by", due to the migratory habits of the species. The scientific name also refers to its migratory characteristics. The morphologically similar mourning dove (*Zenaida macroura*) was long thought to be its closest relative, and the two were at times confused, but genetic analysis has shown that the genus *Patagioenas* is more closely related to it than the *Zenaida* doves.

The passenger pigeon was sexually dimorphic in size and coloration. The male was 39 to 41 cm (15.4 to 16.1 in) in length, mainly gray on the upperparts, lighter on the underparts, with iridescent bronze feathers on the neck, and black spots on the wings. The female was 38 to 40 cm (15.0 to 15.7 in), and was duller and browner than the male overall. The juvenile was similar to the female, but without iridescence. It mainly inhabited the deciduous forests of eastern North America and was also recorded elsewhere, but bred primarily around the Great Lakes. The pigeon migrated in enormous flocks, constantly searching for food, shelter, and breeding grounds, and was once the most abundant bird in North America, numbering around 3 to 5 billion at the height of its population. It was not always as abundant, and the population size fluctuated rapidly over time. A very fast flyer, it could reach 100 km/h (62 mph). The bird fed mainly on mast, and also fruits and invertebrates. It practiced communal roosting and communal breeding, and its extreme gregariousness may be linked with searching for food and predator satiation.

Passenger pigeons were hunted by Native Americans, but hunting intensified after the arrival of Europeans, particularly in the 19th century. Pigeon meat was commercialized as cheap food, resulting in hunting on a massive scale for many decades. There were several other factors contributing to the decline and subsequent extinction of the species, including shrinking of the large breeding populations necessary for preservation of the species and widespread deforestation, which destroyed its habitat. A slow decline between about 1800 and 1870 was followed by a rapid decline between 1870 and 1890. The last confirmed wild bird is thought to have been shot in 1900. The last captive birds were divided in three groups around the turn of the 20th century, some of which were photographed alive. Martha, thought to be the last passenger pigeon, died on September 1, 1914, at the Cincinnati Zoo. The eradication of this species is a notable example of anthropogenic extinction.

Taxonomy

Earliest published illustration of the species (a male), Mark Catesby, 1731

Swedish naturalist Carl Linnaeus coined the binomial name *Columba macroura* for both the mourning dove and the passenger pigeon in the 1758 edition of his work *Systema Naturae* (the starting point of biological nomenclature), wherein he appears to have considered the two identical. This composite description cited accounts of these birds in two pre-Linnean books. One of these was Mark Catesby's description of the passenger pigeon, which was published in his 1731–1743 work *Natural History of Carolina, Florida and the Bahama Islands*, which referred to this bird as *Palumbus migratorius*, and was accompanied by the earliest published illustration of the species. Catesby's description was combined with the 1743 description of the mourning dove by George Edwards, who used the name *C. macroura* for that bird. There is nothing to suggest Linnaeus ever saw specimens of these birds himself, and his description is thought to be fully derivative of these earlier accounts and their illustrations. In his

1766 edition of *Systema Naturae*, Linnaeus dropped the name *C. macroura*, and instead used the name *C. migratoria* for the passenger pigeon, and *C. carolinensis* for the mourning dove. In the same edition, Linnaeus also named *C. canadensis*, based on *Turtur canadensis*, as used by Mathurin Jacques Brisson in 1760. Brisson's description was later shown to have been based on a female passenger pigeon.

In 1827 William John Swainson moved the passenger pigeon from the genus *Columba* to the new monotypic genus *Ectopistes*, due in part to the length of the wings and the wedge shape of the tail. In 1906 Outram Bangs suggested that because Linnaeus had wholly copied Catesby's text when coining *C. macroura*, this name should apply to the passenger pigeon, as *E. macroura*. In 1918 Harry C. Oberholser suggested that *C. canadensis* should take precedence over *C. migratoria* (as *E. canadensis*), as it appeared on an earlier page in Linnaeus' book. In 1952 Francis Hemming proposed that the International Commission on Zoological Nomenclature (ICZN) secure the specific name *macroura* for the mourning dove, and the name *migratorius* for the passenger pigeon, since this was the intended use by the authors on whose work Linnaeus had based his description. This was accepted by the ICZN, which used its plenary powers to designate the species for the respective names in 1955.

Evolution

Stuffed male passenger pigeon, Field Museum of Natural History

The passenger pigeon was a member of the pigeon and dove family, Columbidae. Its closest living relatives were long thought to be the *Zenaida* doves, based on morphological grounds, particularly the physically similar mourning dove (now *Z. macroura*). It was even suggested that the mourning dove belonged to the genus *Ectopistes* and was listed as *E. carolinensis* by some authors, including Thomas Mayo Brewer. The passenger pigeon was supposedly descended from *Zenaida* pigeons that had adapted to the woodlands on the plains of central North America. The passenger pigeon differed from the species in the genus *Zenaida* in being larger, lacking a facial stripe, being sexually dimorphic, and having iridescent neck feathers and a smaller clutch. In a 2002 study by American geneticist Beth Shapiro et al., museum specimens of the passenger pigeon were included in an ancient DNA analysis for the first time (in a paper focusing mainly on the dodo), and it was found to be the sister taxon of the cuckoo-dove genus *Macro-*

pygia. The *Zenaida* doves were instead shown to be related to the quail-doves of the genus *Geotrygon* and the *Leptotila* doves.

Band-tailed pigeon, a species in the related genus *Patagioenas*

The physically similar mourning dove is not closely related.

A more extensive 2010 study instead showed that the passenger pigeon was most closely related to the New World *Patagioenas* pigeons, including the band-tailed pigeon (*P. fasciata*) of western North America, which are related to the Southeast Asian species in the genera *Turacoena*, *Macropygia* and *Reinwardtoena*. This clade is also related to the *Columba* and *Streptopelia* doves of the Old World (collectively termed the "typical pigeons and doves"). The authors of the study suggested that the ancestors of the passenger pigeon may have colonized the New World from South East Asia by flying across the Pacific Ocean, or perhaps across Beringia in the north. In a 2012 study, the nuclear DNA of the passenger pigeon was analyzed for the first time, and its relationship with the *Patagioenas* pigeons was confirmed. In contrast to the 2010 study, these authors suggested that their results could indicate that the ancestors of the passenger pigeon and its Old World relatives may have originated in the Neotropical region of the New World.

The cladogram below follows the 2012 DNA study showing the position of the passenger pigeon among its closest relatives:

DNA in old museum specimens is often degraded and fragmentary, and passenger pigeon specimens have been used in various studies to discover improved methods of analyzing and assembling genomes from such material. DNA samples are often taken from the toe pads of bird skins in museums, as this can be done without causing significant damage to valuable specimens. The passenger pigeon had no known subspecies.

Hybridization occurred between the passenger pigeon and the Barbary dove (*Streptopelia risoria*) in the aviary of Charles Otis Whitman (who owned many of the last captive birds around the turn of the 20th century, and kept them with other pigeon species) but the offspring were infertile.

Etymology

The genus name, *Ectopistes*, translates as "moving about" or "wandering", while the specific name, *migratorius*, indicates its migratory habits. The full binomial can thus be translated as "migratory wanderer". The English common name "passenger pigeon" derives from the French word *passager*, which means "to pass by" in a fleeting manner. While the pigeon was extant, the name passenger pigeon was used interchangeably with "wild pigeon". The bird also gained some less-frequently used names, including blue pigeon, merne rouck pigeon, wandering long-tailed dove, and wood pigeon. In the 18th century, the passenger pigeon was known as *tourte* in New France (in modern Canada), but to the French in Europe it was known as *tourtre*. In modern French, the bird is known as *tourte voyageuse* or *pigeon migrateur*, among other names. In the Native American Algonquian languages, the pigeon was called *amimi* by the Lenape, *omiimii* by the Ojibwe, and *mimia* by the Kaskaskia Illinois. Other names in indigenous American languages include *ori'te* in Mohawk, and *putchee nashoba*, or "lost dove", in Choctaw. The Seneca people called the pigeon *jahgowa*, meaning "big bread", as it was a source of food for their tribes. Chief Simon Pokagon of the Potawatomi stated that his people called the pigeon *O-me-me-wog*, and that the Europeans did not adopt native names for the bird, as it reminded them of their domesticated pigeons, instead calling them "wild" pigeons, as they called the native peoples "wild" men.

Description

Turnaround video of an adult male specimen at Naturalis Biodiversity Center

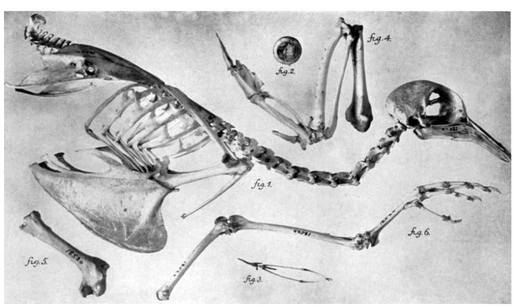
The passenger pigeon was sexually dimorphic in size and coloration. It weighed between 260 and 340 g (9 and 12 oz). The adult male was about 39 to 41 cm (15.4 to 16.1 in) in length. It had a bluish-gray head, nape, and hindneck. On the sides of the neck and the upper mantle were iridescent display feathers that have variously been described as being a bright bronze, violet or golden-green, depending on the angle of the light. The upper back and wings were a pale or slate gray tinged with olive brown, that turned into grayish-brown on the lower wings. The lower back and rump were a dark blue-gray that became grayish-brown on the upper tail-covert feathers. The greater and median wing-covert feathers were pale gray, with a small number of irregular black spots near the end. The primary and secondary feathers of the wing were a blackish-brown with a narrow white edge on the outer side of the secondaries. The two central tail feathers were brownish gray, and the rest were white. The tail pattern was distinctive as it had white outer edges with blackish spots that were prominently displayed in flight. The lower throat and breast were richly pinkish-rufous, grading into a paler pink further down, and into white on the abdomen and undertail covert feathers. The undertail coverts also had a few black spots. The bill was black, while the feet and legs were a bright coral red. It had a carmine-red iris surrounded by a narrow purplish-red eye-ring. The wing of the male measured 196–215 mm (7.7–8.5 in), the tail 175–210 mm (6.9–8.3 in), the bill 15–18 mm (0.59–0.71 in), and the tarsus was 26–28 mm (1.0–1.1 in).

Turnaround video of an adult female specimen at Naturalis

The adult female passenger pigeon was slightly smaller than the male at 38 to 40 cm (15.0 to 15.7 in) in length. It was duller than the male overall, and was a grayish-brown on the forehead, crown, and nape down to the scapulars, and the feathers on the sides of the neck had less iridescence than those of the male. The lower throat and breast were a buff-gray that developed into white on the belly and undertail-coverts. It was browner on the upperparts and paler buff brown and less rufous on the underparts than the male. The wings, back, and tail were similar in appearance to those of the male except that the outer edges of the primary feathers were edged in buff or rufous buff. The wings had more spotting than those of the male. The tail was shorter than that of the male, and the legs and feet were a paler red. The iris was orange red, with a grayish blue, naked orbital ring. The wing of the female was 180–210 mm (7.1–8.3 in), the tail 150–200 mm (5.9–7.9 in), the bill 15–18 mm (0.59–0.71 in), and the tarsus was 25–28 mm (0.98–1.10 in).

Turnaround video of a juvenile female specimen at Naturalis

The juvenile passenger pigeon was similar in plumage to the adult female, but lacked the spotting on the wings, and was a darker brownish-gray on the head, neck, and breast. The feathers on the wings had pale gray fringes (also described as white tips), giving it a scaled look. The secondaries were brownish-black with pale edges, and the tertial feathers had a rufous wash. The primaries were also edged with a rufous-brown color. The neck feathers had no iridescence. The legs and feet were dull red, and the iris was brownish, and surrounded by a narrow carmine ring. The plumage of the sexes was similar during their first year.



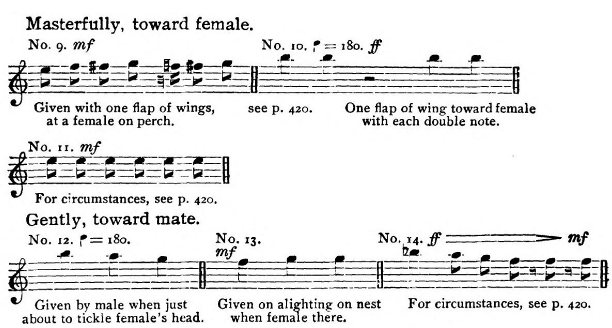
Skeleton of a male bird, 1914

Of the hundreds of surviving skins, only one appears to be aberrant in color—an adult female from the collection of Walter Rothschild, Natural History Museum at Tring. It is a washed brown on the upper parts, wing covert, secondary feathers, and tail (where it would otherwise have been gray), and white on the primary feathers and underparts. The normally black spots are brown, and it is pale gray on the head, lower back, and upper-tail covert feathers, yet the iridescence is unaffected. The brown mutation is a result of a reduction in eumelanin, due to incomplete synthesis (oxidation) of this pigment. This sex-linked mutation is common in female wild birds, but it is thought the white feathers of this specimen are instead the result of bleaching due to exposure to sunlight.

The passenger pigeon was physically adapted for speed, endurance, and maneuverability in flight, and has been described as having a streamlined version of the typical pigeon shape, such as that of the generalized rock dove (*Columba livia*). The wings were very long and pointed, and measured 220 mm (8.7 in) from the wing-chord to the primary feathers, and 120 mm (4.7 in) to the secondaries. The tail, which accounted for much of its overall length, was long and wedge-shaped (or graduated), with two central feathers longer than the rest. The body was slender and narrow, and the head and neck were small.

The internal anatomy of the passenger pigeon has rarely been described. Robert W. Shufeldt found little to differentiate the bird's osteology from that of other pigeons when examining a male skeleton in 1914, but Julian P. Hume noted several distinct features in a more detailed 2015 description. The pigeon had particularly large breast muscles that indicate powerful flight (musculus pectoralis major for downstroke and the smaller musculus supracoracoideus for upstroke). The coracoid bone (which connects the scapula, furcula, and sternum) was large relative to the size of the bird, 33.4 mm (1.31 in), with straighter shafts and more robust articular ends than in other pigeons. The furcula had a sharper V-shape and was more robust, with expanded articular ends. The scapula was long, straight, and robust, and its distal end was enlarged. The sternum was very large and robust compared to that of other pigeons; its keel was 25 mm (0.98 in) deep. The overlapping uncinate processes, which stiffen the ribcage, were very well developed. The wing bones (humerus, radius, ulna, carpometacarpus) were short but robust compared to other pigeons. The leg bones were similar to those of other pigeons.

Vocalizations



Musical notes documenting male vocalizations, compiled by Wallace Craig, 1911

The noise produced by flocks of passenger pigeons was described as deafening, audible for miles away, and the bird's voice as loud, harsh, and unmusical. It was also described by some as clucks, twittering and cooing, and as a series of low notes instead of actual song. The birds apparently made croaking noises when building nests, and bell-like sounds when mating. During feeding, some individuals would give alarm calls when facing a threat, and the rest of the flock would join the sound while taking off.

In 1911 American behavioral scientist Wallace Craig published an account of the gestures and sounds of this species as a series of descriptions and musical notations, based on observation of C. O. Whitman's captive passenger pigeons in 1903. Craig compiled these records to assist in identifying potential survivors in the wild (as the physically similar mourning doves could otherwise be mistaken for passenger pigeons), while noting this "meager information" was likely all that would be left on the subject. According to Craig, one call was a simple harsh "keck" that could be given twice in succession with a pause in between. This was said to be used to attract the attention of another pigeon. Another call was a more frequent and variable scolding. This sound was described as "kee-kee-kee-kee" or "tete! tete! tete!", and was used to call either to its mate or towards other creatures it considered to be enemies. One variant of this call, described as a long, drawn-out "tweet", could be used to call down a flock of passenger pigeons passing overhead, which would then land in a nearby tree. "Keeho" was a soft cooing that, while followed by louder "keck" notes or scolding, was directed at the bird's mate. A nesting passenger pigeon would also give off a stream of at least eight mixed notes that were both high and low in tone and ended with "keeho". Overall, female passenger pigeons were quieter and called infrequently. Craig suggested that the loud, strident voice and "degenerated" musicality was the result of living in populous colonies where only the loudest sounds could be heard.

Distribution and Habitat

The passenger pigeon was found across most of North America east of the Rocky Mountains, from the Great Plains to the Atlantic coast in the east, to the south of Canada in the north, and the north of Mississippi in the southern United States, coinciding with its primary habitat, the eastern deciduous forests. Within this range, it constantly migrated in search of food and shelter. It is unclear if the birds favored particular trees and terrain, but they were possibly not restricted to one type, as long as their numbers could be supported. It originally bred from the southern parts of eastern and central Canada south to eastern Kansas, Oklahoma, Mississippi, and Georgia in the United States, but the primary breeding range was in southern Ontario and the Great Lakes states south through states north of the Appalachian Mountains. Though the western forests were ecologically similar to those in the east, these were occupied by band-tailed pigeons, which may have kept out the passenger pigeons through competitive exclusion.

Specimen in flying pose, Academy of Natural Sciences of Drexel University

The passenger pigeon wintered from Arkansas, Tennessee, and North Carolina south to Texas, the Gulf Coast, and northern Florida, though flocks occasionally wintered as far north as southern Pennsylvania and Connecticut. It preferred to winter in large swamps, particularly those with alder trees; if swamps were not available, forested areas, particularly with pine trees, were favored roosting sites. There were also sightings of passenger pigeons outside of its normal range, including in several Western states, Bermuda, Cuba, and Mexico, particularly during severe winters. It has been suggested that some of these extralimital records may be considered as such more on the basis of the paucity of observers in what was then unsettled country than on the actual extent of wandering passenger pigeons, and that the bird may have appeared anywhere on the continent except for the far west. There were also records of stragglers in Scotland, Ireland, and France, although these birds may have been escaped captives, or the records simply incorrect.

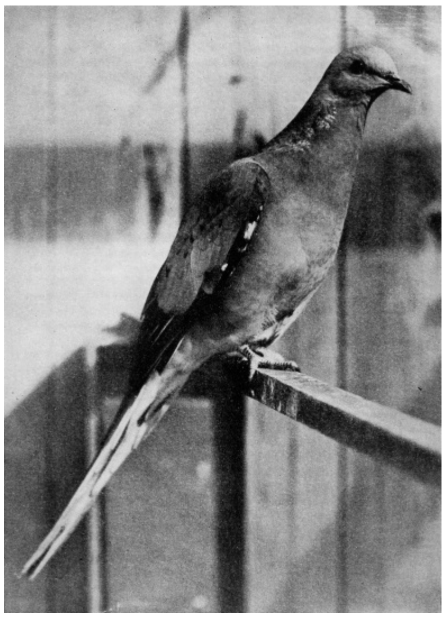
More than 130 passenger pigeon fossils have been found scattered across 25 states and provinces of the United States, including in the La Brea Tar Pits of California. These records date as far back as 100,000 years ago in the Pleistocene era, during which the pigeon's range extended to several western states that were not a part of its modern range. The abundance of the species in these regions and during this time is unknown.

Ecology and Behavior

The passenger pigeon was nomadic, constantly migrating in search of food, shelter, or nesting grounds. In his 1831 *Ornithological Biography*, American naturalist and artist John James Audubon described a migration he observed in 1813 as follows:

I dismounted, seated myself on an eminence, and began to mark with my pencil, making a dot for every flock that passed. In a short time finding the task which I had undertaken impracticable, as the birds poured in in countless multitudes, I rose and, counting the dots then put down, found that 163 had been made in twenty-one minutes. I traveled on, and still met more the farther I proceeded. The air was literally filled with

Pigeons; the light of noon-day was obscured as by an eclipse; the dung fell in spots, not unlike melting flakes of snow, and the continued buzz of wings had a tendency to lull my senses to repose... I cannot describe to you the extreme beauty of their aerial evolutions, when a hawk chanced to press upon the rear of the flock. At once, like a torrent, and with a noise like thunder, they rushed into a compact mass, pressing upon each other towards the center. In these almost solid masses, they darted forward in undulating and angular lines, descended and swept close over the earth with inconceivable velocity, mounted perpendicularly so as to resemble a vast column, and, when high, were seen wheeling and twisting within their continued lines, which then resembled the coils of a gigantic serpent... Before sunset I reached Louisville, distant from Hardensburgh fifty-five miles. The Pigeons were still passing in undiminished numbers and continued to do so for three days in succession.



Live male in Whitman's aviary, 1896/98

These flocks were frequently described as being so dense that they blackened the sky and as having no sign of subdivisions. The flocks ranged from only 1.0 m (3.3 ft) above the ground in windy conditions to as high as 400 m (1,300 ft). These migrating flocks were typically in narrow columns that twisted and undulated, and they were reported as being in nearly every conceivable shape. A skilled flyer, the passenger pigeon is estimated to have averaged 100 km/h (62 mph) during migration. It flew with quick, repeated flaps that increased the bird's velocity the closer the wings got to the body. It was equally as adept and quick at flying through a forest as through open space. A flock was also adept at following the lead of the pigeon in front of it, and flocks swerved together to avoid a predator. When landing, the pigeon flapped its wings repeatedly before raising them at the moment of landing. The pigeon was awkward when on the ground, and moved around with jerky, alert steps.

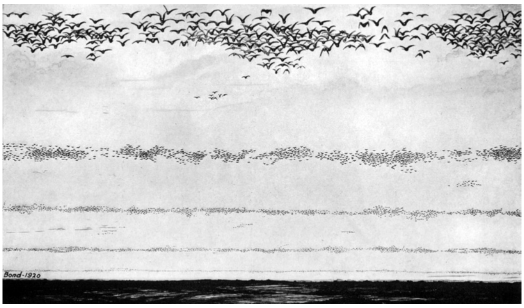
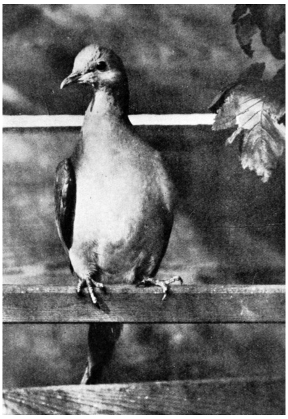


Illustration of migrating flocks, Frank Bond, 1920

The passenger pigeon was one of the most social of all land birds. Estimated to have numbered three to five billion at the height of its population, it may have been the most numerous bird on Earth; researcher Arlie W. Schorger believed that it accounted for between 25 and 40 percent of the total land bird population in the United States. The passenger pigeon's historic population is roughly the equivalent of the number of birds that overwinter in the United States every year in the early 21st century. One flock in 1866 in southern Ontario was described as being 1.5 km (1 mi) wide and 500 km (300 mi) long, took 14 hours to pass, and held in excess of 3.5 billion birds. Such a number would likely represent a large fraction of the entire population at the time, or perhaps all of it. Most estimations of numbers were based on single migrating colonies, and it is unknown how many of these existed at a given time. American writer Christopher Cokinos has suggested that if the birds flew single file, they would have stretched around the earth 22 times. A 2014 genetic study (based on coalescent theory) suggested that the passenger pigeon population fluctuated rapidly across the last million years, due to their dependence on availability of mast (which itself fluctuates). The study suggested the bird was not always abundant, mainly persisting at around 1/10,000 the amount of the several billions estimated in the 1800s. Some early accounts also suggest that the appearance of flocks in great numbers was an irregular occurrence. These large fluctuations in population may have been the result of a disrupted ecosystem and have consisted of outbreak populations much larger than those common in pre-European times.

Juvenile (left), male (center), female (right), Louis Agassiz Fuertes, 1910

A communally roosting species, the passenger pigeon chose roosting sites that could provide shelter and enough food to sustain their large numbers for an indefinite period. The time spent at one roosting site may have depended on the extent of human persecution, weather conditions, or other, unknown factors. Roosts ranged in size and extent, from a few acres to 260 km² (100 sq mi) or greater. Some roosting areas would be reused for subsequent years, others would only be used once. The passenger pigeon roosted in such numbers that even thick branches on a tree would break under the strain. The birds frequently piled on top of each other's backs to roost. They rested in a slumped position that hid their feet. They slept with their bills concealed by the feathers in the middle of the breast while holding their tail at a 45-degree angle. Dung could accumulate under a roosting site to a depth of over 0.3 m (1.0 ft).



Alert parent bird posing defiantly towards the camera

If the pigeon became alert, it would often stretch out its head and neck in line with its body and tail, then nod its head in a circular pattern. When aggravated by another pigeon, it raised it wings threateningly, but passenger pigeons almost never actually fought. The pigeon bathed in shallow water, and afterwards lay on each side in turn and raised the opposite wing to dry it. The passenger pigeon drank at least once a day, typically at dawn, by fully inserting its bill into lakes, small ponds, and streams. Pigeons were seen perching on top of each other to access water, and if necessary, the species could alight on open water to drink. One of the primary causes of natural mortality was the weather, and every spring many individuals froze to death after migrating north too early. In captivity, a passenger pigeon was capable of living at least 15 years; Martha, the last known living passenger pigeon, was at least 17 and possibly as old as 29 when she died. It is undocumented how long a wild pigeon lived.

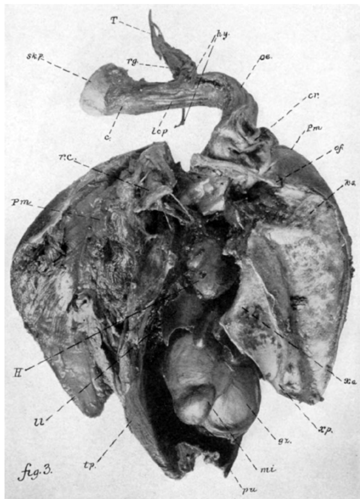
The bird is believed to have played a significant ecological role in the composition of presettlement forests of eastern North America. For instance, while the passenger pigeon was extant, forests were dominated by white oaks. This species germinated in the fall, therefore producing acorns during the spring to be devoured and spread by the pigeons. The absence of the passenger pigeon's seed dispersal may have led to the modern dominance of red oaks. At roosting sites, few plants grew for years after the pigeons left. Also, the immense amount of dung present at these sites increased both the frequency and intensity of forest fires. With the large numbers in the flocks, the excrement they produced was enough to destroy surface-level vegetation, and along with the breaking of treelimbs under their collective weight, the passenger pigeons could do significant damage to forests. Due to these influences, some ecologists have considered the passenger pigeon a keystone species. The American chestnut trees that provided much of the mast on which the passenger pigeon fed was itself almost driven to extinction by an imported Asian fungus (chestnut blight) around 1905. As many as thirty billion trees are thought to have died as a result in the following decades, but this did not affect the passenger pigeon, which was already extinct in the wild at the time.

Diet

Acorns in South Carolina, among the diet of this bird

Beeches and oaks produced the mast needed to support nesting and roosting flocks. The passenger pigeon changed its diet depending on the season. In the fall, winter, and spring, it mainly ate beechnuts, acorns, and chestnuts. During the summer, berries and softer fruits, such as blueberries, grapes, cherries, mulberries, pokeberries, and bunchberry, became the main objects of its consumption. It also ate worms, caterpillars, snails, and other invertebrates, particularly while breeding. Additionally, the passenger pigeon took advantage of cultivated grains, particularly buckwheat, when it found them. The species was especially fond of salt, which it ingested either from brackish springs or salty soil. Mast occurs in large quantities in different places at different times, and rarely in consecutive years, which is one of the reasons why the large flocks were constantly on the move. As mast is produced during autumn, there would have to be a large amount of it left by the summer, when the young were reared. It is unknown how they located this fluctuating food source, but their eyesight and flight powers aided them in surveying large areas for places that could provide food enough for a temporary stay.

The passenger pigeon foraged in flocks of tens or hundreds of thousands of individuals that overturned leaves, dirt, and snow with their bills in a frantic search for large quantities of food. One observer described the motion of such a flock in search of mast as having a rolling appearance, as birds in the back of the flock flew overhead to the front of the flock, dropping leaves and grass in flight. The flocks had wide leading edges to better scan the landscape for food sources. When nuts on a tree loosened from their caps, a pigeon would land on a branch and, while flapping vigorously to stay balanced, grab the nut, pull it loose from its cap, and swallow it whole. Collectively, a foraging flock was capable of removing nearly all fruits and nuts from their path. Birds in the back of the flock flew to the front in order to pick over unsearched ground; however, birds never ventured far from the flock and hurried back if they became isolated. It is believed that the pigeons used social cues in order to identify abundant sources of food, and a flock of pigeons that saw others feeding on the ground often joined them. During the day, the birds left the roosting forest to forage on more open land. They regularly flew 100 to 130 km (62 to 81 mi) away from their roost daily in search of food, and some pigeons reportedly traveled as far as 160 km (99 mi), leaving the roosting area early and returning at night.

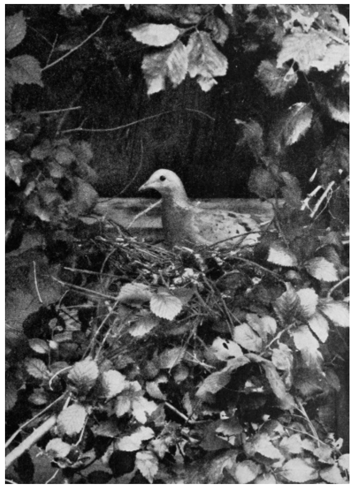


Internal organs of Martha, the last individual: cr. denotes the crop, gz. the gizzard, 1915

The passenger pigeon had a very elastic mouth and throat, allowing for increased capacity, and a joint in the lower bill enabled it to swallow acorns whole. The bird was also able to store large quantities of food in its crop, which was capable of expanding to about the size of an orange, causing the neck to bulge. This allowed a bird to quickly grab any food it discovered in the highly competitive flock. The crop was described as being capable of holding at least 17 acorns or 28 beechnuts, 11 grains of corn, 100 maple seeds, plus other material; it was estimated that a passenger pigeon needed to eat about 61 cm^3 (3.7 in^3) of food a day in order to survive. If shot, a pigeon with a crop full of nuts would fall to the ground with a sound described as like the rattle of a bag of marbles. After feeding, the pigeons perched on branches and digested the food stored in their crop overnight. The pigeon could eat and digest 0.100 kg (0.22 lb) of acorns per day. At the historic population of three billion passenger pigeons, this amounted to 210,000,000 L (55,000,000 US gal) of food a day. The pigeon was also able to regurgitate food from its crop when more desirable food became available.

Reproduction

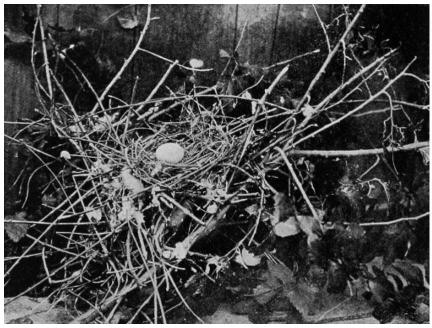
Other than finding roosting sites, the migrations of the passenger pigeon were connected with finding places appropriate for this communally breeding bird to nest and raise its young. It is not certain how many times a year the birds bred; once seems most likely, but some accounts suggest more. The nesting period lasted around four to six weeks. The flock arrived at a nesting ground around March in southern latitudes, and some time later in more northern areas. The pigeon had no site fidelity, often choosing to nest in a different location each year. The formation of a nesting colony did not necessarily take place until several months after the pigeons arrived on their breeding grounds, typically during late March, April, or May.



Nesting captive bird, wary of the photographer

The colonies, which were known as "cities", were immense, ranging from 49 ha (120 acres) to thousands of hectares in size, and were often long and narrow in shape (L-shaped), with a few areas untouched for unknown reasons. Due to the topography, they were rarely continuous. Since no accurate data was recorded, it is not possible to give more than estimates on the size and population of these nesting areas, but most accounts mention colonies containing millions of birds. The largest nesting area ever recorded was in central Wisconsin in 1871; it was reported as covering 2,200 km^2 (850 sq mi), with the number of birds nesting there estimated to be around 136,000,000. As well as these "cities", there were regular reports of much smaller flocks or even individual pairs setting up a nesting site. The birds do not seem to have formed as vast breeding colonies at the periphery of their range.

Courtship took place at the nesting colony. Unlike other pigeons, courtship took place on a branch or perch. The male, with a flourish of the wings, made a "keck" call while near a female. The male then gripped tightly to the branch and vigorously flapped his wings up and down. When the male was close to the female, he then pressed against her on the perch with his head held high and pointing at her. If receptive, the female pressed back against the male. When ready to mate, the pair preened each other. This was followed by the birds billing, in which the female inserted its bill into and clasped the male's bill, shook for a second, and separated quickly while standing next to each other. The male then scrambled onto the female's back and copulated, which was then followed by soft clucking and occasionally more preening. John James Audubon described the courtship of the passenger pigeon as follows:



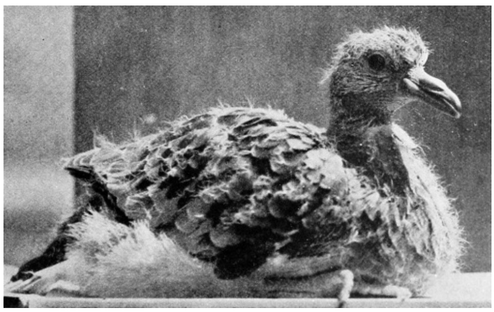
Nest and egg in Whitman's aviary

Thither the countless myriads resort, and prepare to fulfill one of the great laws of nature. At this period the note of the Pigeon is a soft coo-coo-coo-coo much shorter than that of the domestic species. The common notes resemble the monosyllables kee-kee-kee-kee, the first being the loudest, the others gradually diminishing In power. The male assumes a pompous demeanor, and follows the female, whether on the ground or on the branches, with spread tail and drooping wings, which it rubs against the part over which it is moving. The body is elevated, the throat swells, the eyes sparkle. He continues his notes, and now and then rises on the wing, and flies a few yards to approach the fugitive and timorous female. Like the domestic Pigeon and other species, they caress each other by billing, in which action, the bill of the one is introduced transversely into that of the other, and both parties alternately disgorge the contents of their crop by repeated efforts.

After observing captive birds, Wallace Craig found that this species did less charging and strutting than other pigeons (as it was awkward on the ground), and thought it probable that no food was transferred during their brief billing (unlike in other pigeons), and he therefore considered Audubon's description partially based on analogy with other pigeons as well as imagination.

Preserved egg, Muséum de Toulouse

Nests were built immediately after pair formation and took two to four days to construct; this process was highly synchronized within a colony. The female chose the nesting site by sitting on it and flicking its wings. The male then carefully selected nesting materials, typically twigs, and handed them to the female over her back. The male then went in search of more nesting material while the female constructed the nest beneath herself. Nests were built between 2.0 and 20.1 m (6.6 and 65.9 ft) above the ground, though typically above 4.0 m (13.1 ft), and were made of 70 to 110 twigs woven together to create a loose, shallow bowl through which the egg could easily be seen. This bowl was then typically lined with finer twigs. The nests were about 15 cm (5.9 in) wide, 6.1 cm (2.4 in) high, and 1.9 cm (0.75 in) deep. Though the nest has been described as crude and flimsy compared to those of many other birds, remains of nests could be found at sites where nesting had taken place several years prior. Nearly every tree capable of supporting nests had them, often more than 50 per tree; one hemlock was recorded as holding 317 nests. The nests were placed on strong branches close to the tree trunks. Some accounts state that ground under the nesting area looked as if it had been swept clean, due to all the twigs being collected at the same time, yet this area would also have been covered in dung. As both sexes took care of the nest, the pairs were monogamous for the duration of the nesting.

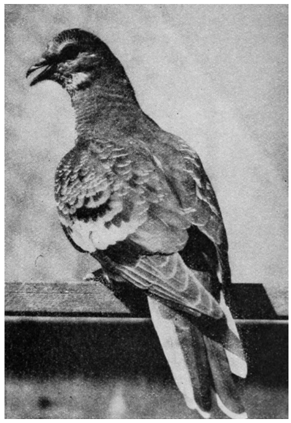


Live nestling or squab

Generally, the eggs were laid during the first two weeks of April across the pigeon's range. Each female laid its egg immediately or almost immediately after the nest was completed; sometimes the pigeon was forced to lay it on the ground if the nest was not complete. The normal clutch size appears to have been a single egg, but there is some uncertainty about this, as two have also been reported from the same nests. Occasionally, a second female laid its egg in another female's nest, resulting in two eggs being present. The egg was white and oval shaped and averaged 40 mm (1.6 in) by 34 mm (1.3 in) in size. If the egg was lost, it was possible for the pigeon to lay a replacement egg within a week. A whole colony was known to re-nest after a snowstorm forced them to abandon their original colony. The egg was incubated by both parents for 12 to 14 days, with the male incubating it from midmorning to midafternoon and the female incubating it for the rest of the time.

Upon hatching, the nestling (or squab) was blind and sparsely covered with yellow, hairlike down. The nestling developed quickly and within 14 days weighed as much as its parents. During this brooding period both parents took care of the nestling, with the male attending in the middle of the day and the female at other times. The nestlings were fed crop milk (a substance similar to curd, produced in the crops of the parent birds) exclusively for the first days after hatching. Adult food was gradually introduced after three to six days. After 13 to 15 days, the parents fed the nestling for a last time and then abandoned it, leaving the nesting area *en masse*. The nestling begged in the nest for a day or two, before climbing from the nest and fluttering to the ground, whereafter it moved around, avoided obstacles, and begged for food from nearby adults. It was another three or four days before it fledged. The entire nesting cycle lasted about 30 days. It is unknown whether colonies re-nested after a successful nesting. The passenger pigeon sexually matured during its first year and bred the following spring.

Predators and Parasites



Immature bird; the young were vulnerable to predators after leaving the nest

Nesting colonies attracted large numbers of predators, including American minks, American weasels, American martens, and raccoons that preyed on eggs and nestlings, birds of prey, such as owls, hawks, and eagles that preyed on nestlings and adults, and wolves, foxes, bobcats, bears, and mountain lions that preyed on injured adults and fallen nestlings. Hawks of the genus *Accipiter* and falcons pursued and preyed upon pigeons in flight, which in turn executed complex aerial maneuvers to avoid them; Cooper's hawk was known as the "great pigeon hawk" due to its successes, and these hawks allegedly followed migrating passenger pigeons. While many predators were drawn to the flocks, individual pigeons were largely protected due to the sheer size of the flock, and overall little damage could be inflicted on the flock by predation. Despite the number of predators, nesting colonies were so large that they were estimated to have a 90% success rate if not disturbed. After being abandoned and leaving the nest, the very fat juveniles were vulnerable to predators until they were able to fly. The sheer number of juveniles on the ground meant that only a small percentage of them were killed; predator satiation may therefore be one of the reasons for the extremely social habits and communal breeding of the species.

Two parasites have been recorded on passenger pigeons. One species of phtilopterid louse, *Columbicola extinctus*, was originally thought to have lived on just passenger pigeons and to have become coextinct with them. This was proven inaccurate in 1999 when *C. extinctus* was rediscovered living on band-tailed pigeons. This, and the fact that the related louse *C. angustus* is mainly found on cuckoo-doves, further supports the relation between these pigeons, as the phylogeny of lice broadly mirrors that of their hosts. Another louse, *Campanulotes defectus*, was thought to have been unique to the passenger pigeon, but is now believed to have been a case of a contaminated specimen, as the species is considered to be the still-extant *Campanulotes flavus* of Australia. There is no record of a wild pigeon dying of either disease or parasites.

Relationship with Humans

The passenger pigeon played a religious role for some northern Native American tribes. The Wyandot people (or Huron) believed that every twelve years during the Feast of the Dead, the souls of the dead changed into passenger pigeons, which were then hunted and eaten. Before hunting the juvenile pigeons, the Seneca people made an offering of wampum and brooches to the old passenger pigeons; these were placed in a small kettle or other receptacle by a smoky fire. The Ho-Chunk people considered the passenger pigeon to be the bird of the chief, as they were served whenever the chieftain gave a feast. The Seneca people believed that a white pigeon was the chief of the passenger pigeon colony, and that a Council of Birds had decided that the pigeons had to give their bodies to the Seneca because they were the only birds that nested in colonies. The Seneca developed a pigeon dance as a way of showing their gratitude.

Billing pair by John James Audubon, from *The Birds of America*, 1827–1838

French explorer Jacques Cartier was the first European to report on passenger pigeons, during his voyage in 1534. The bird was subsequently observed and noted by historical figures such as Samuel de Champlain and Cotton Mather. Most early accounts dwell on the vast number of pigeons, the resulting darkened skies, and the enormous amount of hunted birds (50,000 birds were reportedly sold at a Boston market in 1771). The early colonists thought that large flights of pigeons would be followed by ill fortune or sickness. When the pigeons wintered outside of their normal range, some believed that they would have “a sickly summer and autumn.” In the 18th and 19th centuries, various parts of the pigeon were thought to have medicinal properties. The blood was supposed to be good for eye disorders, the powdered stomach lining was used to treat dysentery, and the dung was used to treat a variety of ailments, including headaches, stomach pains, and lethargy. Though they did not last as long as the feathers of a goose, the feathers of the passenger pigeon were frequently used for bedding. Pigeon feather beds were so popular that for a time in Saint-Jérôme, Quebec, every dowry included a bed and pillows made of pigeon feathers. In 1822, one family in Chautauqua County, New York, killed 4,000 pigeons in a day solely for this purpose.

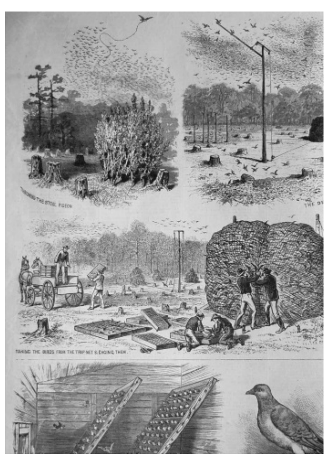
Painting of a male, K. Hayashi, c. 1900

The passenger pigeon was featured in the writings of many significant early naturalists, as well as accompanying illustrations. Mark Catesby's 1731 illustration, the first published depiction of this bird, is somewhat crude, according to some later commentators. The original watercolor that the engraving is based on was bought by the British royal family in 1768, along with the rest of Catesby's watercolors. The naturalists Alexander Wilson and John James Audubon both witnessed large pigeon migrations first hand, and published detailed accounts wherein both attempted to deduce the total number of birds involved. The most famous and often reproduced depiction of the passenger pigeon is Audubon's illustration (handcolored aquatint) in his book *The Birds of America*, published between 1827 and 1838. Audubon's image has been praised for its artistic qualities, but criticized for its supposed scientific inaccuracies. As Wallace Craig and R. W. Shufeldt (among others) pointed out, the birds are shown perched and billing one above the other, whereas they would instead have done this side by side, the male would be the one passing food to the female, and the male's tail would not be spread. Craig and Shufeldt instead cited illustrations by American artist Louis Agassiz Fuertes and Japanese artist K. Hayashi as more accurate depictions of the bird. Illustrations of the passenger pigeon were often drawn after stuffed birds, and Charles R. Knight is the only "serious" artist known to have drawn the species from life. He did so on at least two occasions; in 1903 he drew a bird possibly in one of the three aviaries with surviving birds, and some time before 1914, he drew Martha, the last individual, in the Cincinnati Zoo. The bird has been written about (including in poems, songs, and fiction) and illustrated by many notable writers and artists, and is depicted in art to this day, for example in Walton Ford's 2002 painting *Falling Bough*, and National Medal of Arts winner John A. Ruthven's 2014 mural in Cincinnati, which commemorates the 100th anniversary of Martha's death.

Hunting

The passenger pigeon was an important source of food for the people of North America. The indigenous peoples ate pigeons, and tribes near nesting colonies would sometimes move to live closer to them and eat the juveniles, killing them at night with long poles. Many Native Americans were careful not to disturb the adult pigeons, and instead ate only the juveniles as they were afraid that the adults might desert their nesting grounds; in some tribes, disturbing the adult pigeons was considered a crime. Away from the nests, large nets were used to capture adult pigeons, sometimes up to 800 at a time. Low-flying pigeons could be killed by throwing sticks or stones. At one site in Oklahoma, the pigeons leaving their roost every morning flew low enough that the Cherokee could throw clubs into their midst, which caused the lead pigeons to try to turn aside and in the process created a blockade that resulted in a large mass of flying, easily hit pigeons. Among the game birds, passenger pigeons were second only to the wild turkey (*Meleagris gallopavo*) in terms of importance for the Native Americans living in the southeastern United States. The bird's fat was stored, often in large quantities, and used as butter. Archaeological evidence supports the idea that Native Americans ate the pigeons frequently prior to colonization.

Depiction of a shooting in northern Louisiana, Smith Bennett, 1875



1881 spread showing methods of trapping pigeons for shooting contests

After European colonization, the passenger pigeon was hunted more intensely and with more sophisticated methods than the more sustainable methods practiced by the natives. Yet it has also been suggested that the species was rare prior to 1492, and that the subsequent increase in their numbers may be due to the decrease in the Native American population (who, as well as hunting the birds, competed with them for mast) caused by European immigration, and the supplementary food (agricultural crops) the immigrants provided. It was of particular value on the frontier, and some settlements counted on the pigeon to support their population. The flavor of the flesh of passenger pigeons varied depending on how they were prepared. In general, juveniles were thought to taste the best, followed by birds fattened in captivity and birds caught in September and October. It was common practice to fatten trapped pigeons before eating them or storing their bodies for winter. Dead pigeons were commonly stored by salting or pickling the bodies; other times, only the breasts of the pigeons were kept, in which case they were typically smoked. In the early 19th century, commercial hunters began netting and shooting the birds to sell as food in city markets, and even as pig fodder. Once pigeon meat became popular, commercial hunting started on a prodigious scale.

Pigeon net in Canada, by James Pattison Cockburn, 1829

Passenger pigeons were shot with such ease that many did not consider them to be a game bird, as an amateur hunter could easily bring down six with one shotgun blast; a particularly good shot with both barrels of a shotgun at a roost could kill 61 birds. The birds were frequently shot either in flight during migration or immediately after, when they commonly perched in dead, exposed trees. Hunters only had to shoot toward the sky without aiming, and many pigeons would be brought down. The pigeons proved difficult to shoot head-on, so hunters typically waited for the flocks to pass overhead before shooting them. Trenches were sometimes dug and filled with grain so that a hunter could shoot the pigeons along this trench. Hunters largely outnumbered trappers, and hunting passenger pigeons was a popular sport for young boys. In 1871, a single seller of ammunition provided three tons of powder and 16 tons (32,000 lb) of shot during a nesting. In the latter half of the 19th century, thousands of passenger pigeons were captured for use in the sports shooting industry. The pigeons were used as living targets in shooting tournaments, such as “trap-shooting”, the controlled release of birds from special traps.

Competitions could also consist of people standing regularly spaced while trying to shoot down as many birds as possible in a passing flock. The pigeon was considered so numerous that 30,000 birds had to be killed to claim the prize in one competition.

There were a wide variety of other methods used to capture and kill passenger pigeons. Nets were propped up to allow passenger pigeons entry, then closed by knocking loose the stick that supported the opening, trapping twenty or more pigeons inside. Tunnel nets were also used to great effect, and one particularly large net was capable of catching 3,500 pigeons at a time. These nets were used by many farmers on their own property as well as by professional trappers. Food would be placed on the ground near the nets to attract the pigeons. Decoy or "stool pigeons" (sometimes blinded by having their eyelids sewn together) were tied to a stool. When a flock of pigeons passed by, a cord would be pulled that made the stool pigeon flutter to the ground, making it seem as if it had found food, and the flock would be lured into the trap. Salt was also frequently used as bait, and many trappers set up near salt springs. At least one trapper used alcohol-soaked grain as bait to intoxicate the birds and make them easier to kill. Another method of capture was to hunt at a nesting colony, particularly during the period of a few days after the adult pigeons abandoned their nestlings, but before the nestlings could fly. Some hunters used sticks to poke the nestlings out of the nest, while others shot the bottom of a nest with a blunt arrow to dislodge the pigeon. Others cut down a nesting tree in such a way that when it fell, it would also hit a second nesting tree and dislodge the pigeons within. In one case, 6 km^2 (1,500 acres) of large trees were speedily cut down to get birds, and such methods were common. A severe method was to set fire to the base of a tree nested with pigeons; the adults would flee and the juveniles would fall to the ground. Sulfur was sometimes burned beneath the nesting tree to suffocate the birds, which fell out of the tree in a weakened state.

By the mid-19th century, railroads had opened new opportunities for pigeon hunters. While previously it had proved too difficult to ship masses of pigeons to eastern cities, the access provided by the railroad permitted pigeon hunting to become commercialized. An extensive telegraph system was introduced in the 1860s, which improved communication across the United States, making it easier to spread information about the whereabouts of pigeon flocks. After being opened up to the railroads, the town of Plattsburg, New York is estimated to have shipped 1.8 million pigeons to larger cities in 1851 alone at a price of 31 to 56 cents a dozen. By the late 19th century, the trade of passenger pigeons had become commercialized. Large commission houses employed trappers (known as "pigeoners") to follow the flocks of pigeons year-round. A single hunter is reported to have sent three million birds to eastern cities during his career. In 1874, at least 600 people were employed as pigeon trappers, a number which grew to 1,200 by 1881. Pigeons were caught in such numbers that by 1876, shipments of dead pigeons were unable to recoup the costs of the barrels and ice needed to ship them. The price of a barrel full of pigeons dropped to below fifty cents, due to overstocked markets. Passenger pigeons were instead kept alive so their meat would be fresh when the birds were killed, and sold once their market value had increased again. Thousands of birds were kept in large pens, though the bad conditions led many to die from lack of food and water, and by fretting (gnawing) themselves; many rotted away before they could be sold.

Trapper Albert Cooper with blind decoy pigeons for luring wild birds, c. 1870

Hunting of passenger pigeons was documented and depicted in contemporaneous newspapers, wherein various trapping methods and uses were featured. The most often reproduced of these illustrations was captioned "Winter sports in northern Louisiana: shooting wild pigeons", and published in 1875. Passenger pigeons were also seen as agricultural pests, since entire crops could be destroyed by feeding flocks. The bird was described as a "perfect scourge" by some farming communities, and hunters were employed to "wage warfare" on the birds to save grain, as shown in another newspaper illustration from 1867 captioned as "Shooting wild pigeons in Iowa". When comparing these "pests" to the bison of the Great Plains, it is possible to infer that the valuable resource needed was not the species of animals but the agriculture which was consumed by said animal. The crops that were eaten were seen as marketable calories, proteins, and nutrients all grown for the wrong species.

Decline and Conservation Attempts

The notion that the species could be driven to extinction was alien to the early colonists, both because the number of birds did not appear to diminish, but also because the concept of extinction itself was yet to be defined. The bird seems to have been slowly pushed westwards since the arrival of Europeans, becoming scarce or absent in the east, though there were still millions of birds in the 1850s. The population must have been decreasing in numbers for many years, though this went unnoticed due to the apparent vast number of birds, which clouded their decline. In 1856 Bénédict Henry Révoil may have been one of the first writers to voice concern about the fate of the passenger pigeon, after witnessing a hunt in 1847:

Male and female by Louis Agassiz Fuertes, frontispiece of William Butts Mershon's 1907 *The Passenger Pigeon*

Everything leads to the belief that the pigeons, which cannot endure isolation and are forced to flee or to change their way of living according to the rate at which North America is populated by the European inflow, will simply end by disappearing from this continent, and, if the world does not end this before a century, I will wager... that the amateur of ornithology will find no more wild pigeons, except those in the Museums of Natural History.

Life drawing by Charles R. Knight, 1903

By the 1870s, the decrease in birds was noticeable, especially after the last large scale nestings and subsequent slaughters of millions of birds in 1874 and 1878. By this time, large nestings only took place in the north, around the Great Lakes. The last large nesting was in Petoskey, Michigan, in 1878 (following one in Pennsylvania a few days earlier), where 50,000 birds were killed each day for nearly five months. The surviving adults attempted a second nesting at new sites, but were killed by professional hunters before they had a chance to raise any young. Scattered nestings are reported into the 1880s, but the birds were now wary, and commonly abandoned their nests if persecuted.

By the time of these last nestings, laws had already been enacted to protect the passenger pigeon, but these proved ineffective, as they were unclearly framed and hard to enforce. H. B. Roney, who had witnessed the Petoskey slaughter, led campaigns to protect the pigeon, but was met with resistance, and accusations that he was exaggerating the severity of the situation. Few offenders were prosecuted, mainly some poor trappers, but the large enterprises were not affected. In 1857, a bill was brought forth to the Ohio State Legislature seeking protection for the passenger pigeon, yet a Select Committee of the Senate filed a report stating that the bird did not need protection, being “wonderfully prolific”, and dismissing the suggestion that the species could be destroyed. Public protests against trap-shooting erupted in the 1870s, as the birds were badly treated before and after such contests. Conservationists were ineffective in stopping the slaughter. A bill was passed in the Michigan legislature making it illegal to net pigeons within 3 km (2 miles) of a nesting area. In 1897, a bill was introduced in the Michigan legislature asking for a 10-year closed season on passenger pigeons. Similar legal measures were passed and then disregarded in Pennsylvania. The gestures proved futile, and by the mid-1890s, the passenger pigeon had almost completely disappeared, and was probably extinct as a breeding bird in the wild. Small flocks are known to have existed at this point, since large numbers of birds were still being sold at markets. Thereafter, only small groups or individual birds were reported, many of which were shot on sight.

Last Survivors

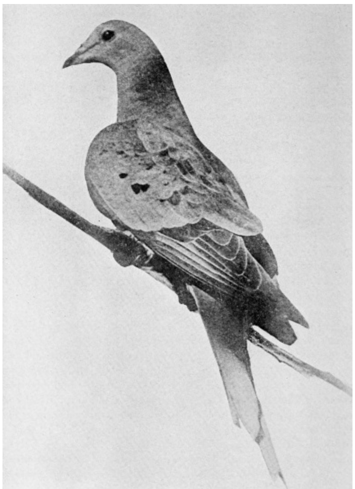
“Buttons”, the last confirmed wild passenger pigeon, Cincinnati Zoo

The last recorded nest and egg in the wild were collected in 1895 near Minneapolis. The last wild individual in Louisiana was discovered among a flock of mourning doves in 1896, and subsequently shot. Many late sightings are thought to be false or due to confusion with mourning doves. The last fully authenticated record of a wild passenger pigeon was near Sargents, Pike County, Ohio, on March 22 or 24, 1900, when a female bird was killed by a boy named Press Clay Southworth with a BB gun. The boy had not recognized the bird as a passenger pigeon, but his parents identified it, and sent it to a taxidermist. The specimen, nicknamed “Buttons” due to the buttons used instead of glass eyes, was donated to the Ohio Historical Society by the family in 1915. Though this is the most often cited last wild specimen, in 2014, writer Joel Greenberg pointed out two later records, one of which involves a male shot in 1902 in Indiana, that was stuffed but later destroyed. The reliability of later accounts are in question. US President Theodore Roosevelt claimed to have seen a bird in Michigan in 1907. Ornithologist Alexander Wetmore claimed that he saw a pair flying near Independence, Kansas, in April 1905. In 1910, the American Ornithologists' Union offered a reward of $3,000 for discovering a nest – the equivalent of $76,990 in 2015.

Whitman's aviary with passenger pigeons and other species, 1896/98

Most captive passenger pigeons were kept for exploitative purposes, but some were housed in zoos and aviaries. Audubon alone claimed to have brought 350 birds to England in 1830, distributing them among various noblemen, and the species is also known to have been kept at London Zoo. Being common birds, these attracted little interest, until the species became rare in the 1890s. By the turn of the 20th century, the last known captive passenger pigeons were divided in three groups; one in Milwaukee, one in Chicago, and one in Cincinnati. There are claims of a few further individuals having been kept in various places, but these accounts are not considered reliable today. The Milwaukee group was kept by David Whittaker, who began his collection in 1888, and possessed fifteen birds some years later, all descended from a single pair.

The Chicago group was kept by Charles Otis Whitman, whose collection began with passenger pigeons bought from Whittaker beginning in 1896. He had an interest in studying pigeons, and kept his passenger pigeons with other pigeon species. Whitman brought his pigeons with him from Chicago to Massachusetts by railcar each summer. By 1897, Whitman had bought all of Whittaker's birds, and upon reaching a maximum of 19 individuals, he gave seven back to Whittaker in 1898. Around this time, a series of photographs were taken of these birds; 24 of the photos survive to this day. Some of these images have been reproduced in various media, copies of which are now kept at the Wisconsin Historical Society. It is unclear exactly where, when, and by whom these photos were taken, but some appear to have been taken in Chicago in 1896, others in Massachusetts in 1898, the latter by a J. G. Hubbard. By 1902, Whitman owned sixteen birds. Many eggs were laid by his pigeons, but few hatched, and many hatchlings died. A newspaper inquiry was published that requested "fresh blood" to the flock which had now ceased breeding. By 1907, he was down to two female passenger pigeons that died that winter, and was left with two infertile male hybrids, whose subsequent fate is unknown. By this time, only four (all males) of the birds Whitman had returned to Whittaker were alive, and these died between November 1908 and February 1909.



Martha, the last passenger pigeon, alive in 1912

The Cincinnati Zoo, one of the oldest zoos in the US, kept passenger pigeons from its beginning in 1875. The zoo kept more than twenty individuals, in a ten-by-twelve-foot cage. Passenger pigeons do not appear to have been kept at the zoo due to their rarity, but to enable guests to have a closer look at a native species. Recognizing the decline of the wild populations, Whitman and the Cincinnati Zoo consistently strove to breed the surviving birds, including attempts at making a rock dove foster passenger pigeon eggs. In 1902, Whitman gave a female passenger pigeon to the zoo; this was possibly the individual later known as Martha, which would become the last living member of the species. Other sources argue that Martha was hatched at the Cincinnati Zoo, had lived there for 25 years, and was the descendant of three pairs of passenger pigeons purchased by the zoo in 1877. It is thought this individual was named Martha because her last cage mate was named George, thereby honoring George Washington and his wife Martha, though it has also been claimed she was named after the mother of a zoo-keeper's friends.

In 1909, Martha and her two male companions at the Cincinnati Zoo became the only known surviving passenger pigeons. One of these males died around April that year, followed by George, the remaining male, on July 10, 1910. It is unknown whether the remains of George were preserved. Martha soon became a celebrity due to her status as an endling, and offers of a $1,000 reward for finding a mate for her brought even more visitors to see her. During her last four years in solitude (her cage was 5.4 by 6 m (18 by 20 ft)), Martha became steadily slower and more immobile; visitors would throw sand at her to make her move, and her cage was roped off in response. Martha died of old age on September 1, 1914, and was found lifeless on the floor of her cage. It was claimed that she died at 1 p.m., but other sources suggest she died some hours later. Depending on the source, Martha was between 17 and 29 years old at the time of her death, although 29 is the generally accepted figure. At the time, it was suggested that Martha might have died from an apoplectic stroke, as she had suffered one a few weeks before dying. Her body was frozen into a block of ice and sent to the Smithsonian Institution in Washington, where it was skinned, dissected, photographed, and mounted. As she was molting when she died, she proved difficult to stuff, and previously shed feathers were added to the skin. Martha was on display for many years, but after a period in the museum vaults, she was put back on display at the Smithsonian's National Museum of Natural History in 2015. A memorial statue of Martha stands on the grounds of the Cincinnati Zoo, in front of the "Passenger Pigeon Memorial Hut", formerly the aviary wherein Martha lived, now a National Historic Landmark. Incidentally, the last specimen of the extinct Carolina parakeet, named "Incus," died in Martha's cage in 1918; the stuffed remains of that bird are exhibited in the "Memorial Hut".

Extinction Causes

Martha at the Smithsonian Museum, 2015

The main reasons for the extinction of the passenger pigeon were the massive scale of hunting, the rapid loss of habitat, and the extremely social lifestyle of the bird, which made it highly vulnerable to the former factors. Deforestation was driven by the need to free land for agriculture and expanding towns, but also due to the demand for lumber and fuel. About 728,000 km^2 (180 million acres) were cleared for farming between 1850 and 1910. Though there are still large woodland areas in eastern North America, which support a variety of wildlife, it was not enough to support the vast number of passenger pigeons needed to sustain the population. In contrast, very small populations of nearly extinct birds, such as the kakapo (*Strigops habroptilus*) and the takahē (*Porphyrio hochstetteri*), have been enough to keep those species extant to the present. The combined effects of intense hunting and deforestation has been referred to as a "Blitzkrieg" against the passenger pigeon, and it has been labeled one of the greatest and most senseless human-induced extinctions in history. As the flocks dwindled in size, the passenger pigeon population decreased below the threshold necessary to propagate the species.

Pigeons being shot to save crops in Iowa, 1867

The 2014 study that demonstrated natural fluctuations in population numbers prior to human arrival also showed that the species routinely recovered from lows in the population, and suggested that one of these lows may have coincided with the intensified exploitation by humans in the 1800s, a combination which would have led to the rapid extinction of the species. A similar scenario may also explain the rapid extinction of the Rocky Mountain locust (*Melanoplus spretus*) during the same period. It has also been suggested that after the population was thinned out, it would be harder for few or solitary birds to locate suitable feeding areas. In addition to the birds killed or driven away by hunting during breeding seasons, many nestlings were also orphaned before being able to fend for themselves. Other, less convincing contributing factors have been suggested at times, including mass drownings, Newcastle disease, and migrations to areas outside their original range.

The extinction of the passenger pigeon aroused public interest in the conservation movement, and resulted in new laws and practices which prevented many other species from becoming extinct. The rapid decline of the passenger pigeon has influenced later assessment methods of the extinction risk of endangered animal populations. The International Union for the Conservation of Nature (IUCN) has used the passenger pigeon as an example in cases where a species was declared "at risk" for extinction even though population numbers are high.

Re-creation of the Species

Taxidermied male and female, Laval University Library

Today, more than 1,532 passenger pigeon skins (along with 16 skeletons) are in existence, spread across many institutions all over the world. It has been suggested that the passenger pigeon should be revived when available technology allows it (a concept which has been termed "de-extinction"), using genetic material from such specimens. In 2003, the Pyrenean ibex (*Capra pyrenaica pyrenaica*, a subspecies of the Spanish ibex) was the first extinct animal to be cloned back to life; the clone lived for only seven minutes before dying of lung defects. A hindrance to cloning the passenger pigeon is the fact that the DNA of museum specimens has been contaminated and fragmented, due to exposure to heat and oxygen. American geneticist George M. Church has proposed that the passenger pigeon genome can be reconstructed by piecing together DNA fragments from different specimens. The next step would be to splice these genes into the stem cells of rock pigeons (or band-tailed pigeons), which would then be transformed into egg and sperm cells, and placed into the eggs of rock pigeons, resulting in rock pigeons bearing passenger pigeon sperm and eggs. The offspring of these would have passenger pigeon traits, and would be further bred to favor unique features of the extinct species.

The general idea of re-creating extinct species has been criticized, since the large funds needed could be spent on conserving currently threatened species and habitats, and because conservation efforts might be viewed as less urgent. In the case of the passenger pigeon, since it was very social, it is unlikely that enough birds could be created for revival to be successful, and it is unclear whether there is enough appropriate habitat left for its reintroduction. Furthermore, the parent pigeons that would raise the cloned passenger pigeons would belong to a different species, with a different way of rearing young.

Asiatic Lion

The Asiatic lion (*Panthera leo persica*), also known as the Indian lion or Persian lion, is a lion subspecies that exists as a single population in India's Gujarat state. Some Asiatic lions also live in zoos. It is listed as Endangered by IUCN due to its small population size. Since 2010, the lion population in the Gir Forest National Park has steadily increased.

In May 2015, the 14th Asiatic Lion Census was conducted over an area of about 20,000 km^2 (7,700 sq mi); the lion population was estimated at 523 individuals, comprising 109 adult males, 201 adult females and 213 cubs.

The Asiatic lion was first described by the Austrian zoologist Johann N. Meyer under the trinomen *Felis leo persicus*.

The Asiatic lion is one of five big cat species found in India, along with Bengal tiger, Indian leopard, snow leopard and clouded leopard. The former habitat of the species included Southeastern Europe, Black Sea Basin, Caucasus, Persia, Canaan, Mesopotamia, Baluchistan, from Sindh in the west to Bengal in the east, and from Rampur and Rohilkund in the north to Nerbudda in the south. It differs from the African lion by less inflated auditory bullae, a larger tail tuft and a less developed mane.

Taxonomic History

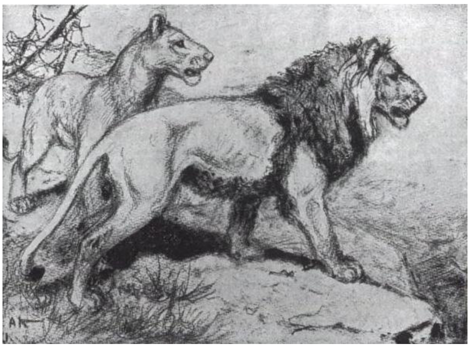
Following Meyer's first description of an Asiatic lion skin from Persia, other naturalists and zoologists also described lions from other parts of Asia that today are all considered synonyms of *P. l. persica*:

- In 1829, Edward Turner Bennett published a book about the animals kept in the Tower Menagerie. His essay about lions contains a drawing titled "Bengal lion *Felis leo bengalensis*".

- In 1833, Walter Smee exhibited two skins of lions killed in Gujerat in a meeting of the Zoological Society of London. He presented these skins of maneless lions under the name *Felis leo goojratensis*.
- In 1834, Sir William Jardine, 7th Baronet proposed the name *Leo asiaticus* for Asiatic lions.
- In 1843, Henri Marie Ducrotay de Blainville published a drawing of an Asiatic lion skull under the name *Felis leo indicus*.

Evolution

Fossil remains found in the Cromer Stage suggest that the lion that entered Europe was of a gigantic size. Frequently encountered lion bones in cave deposits from Eemian times suggest that the late Pleistocene European cave lion, *Panthera leo spelaea*, survived in the Balkans and Asia Minor. There was probably a continuous population extending into India. Cave lions appeared about 600,000 years ago and were distributed throughout Europe, across Siberia and into western Alaska. The gradual formation of dense forest likely caused the decline in geographic range of lions near the end of the late Pleistocene.



Panthera leo persica. Sketch by A. M. Komarov

Phylogenetic analysis of cave lion DNA samples showed that they were highly distinct from their living relatives, and represent lineages that were isolated from lions in Africa and Asia ever since their dispersal over Europe in prehistoric times, and became extinct without mitochondrial descendants on other continents.

Fossil remains of lions were found in Pleistocene deposits in West Bengal. A fossil carnassial found in the Batadomba Cave indicates that *Panthera leo sinhaleyus* inhabited Sri Lanka during the late Pleistocene, and is thought to have become extinct around 39,000 years ago. This subspecies was described by Deraniyagala in 1939. It is distinct from the extant Asiatic lion.

Modern Lions

A phylogeographic analysis based on mtDNA sequences of lions from across their entire range indicates that Sub-Saharan African lions are phylogenetically basal to all modern lions. These findings support an African origin of modern lion evolution with a probable center in eastern–southern Africa, from where lions migrated to West Africa, eastern North Africa and via the periphery of the Arabian Peninsula into Turkey, southern Europe and northern India during the last 20,000 years. Natural barriers to lion dispersal comprise the Sahara Desert, equatorial rainforests and the Great Rift Valley.

African (above) and Asiatic (below) lions, as illustrated in *Johnsons Book of Nature*

Despite the geographical difference between Asiatic and African lions, results of a phylogeographic analysis based on mtDNA and genetic research indicated that Atlas and Senegal lions were more closely related to Asiatic lions than to other African lions. In a comprehensive study about the evolution of lions, 357 samples of 11 lion populations were examined. Results indicate that four 'Atlas' lions from Morocco did not exhibit any unique genetic characteristics. The Moroccan cats shared mitochondrial haplotypes (H5 and H6) with *Panthera leo senegalensis*, and together with them were part of a major mtDNA grouping (lineage III) that also included Asiatic samples. According to the authors, this scenario was in line with their theories on lion evolution. They conclude that lineage III developed in Eastern Africa, and then traveled north and west in the first wave of lion expansions out of the region some 118,000 years ago. It apparently broke up into haplotypes H5 and H6 within Africa, and then into H7 and H8 in Western Asia.

Characteristics

The most striking morphological character, which is always seen in Asiatic lions, and seldom in African lions, is a longitudinal fold of skin running along its belly. Indian lions are smaller than large African lions, and Pocock said that they were similar in size to Central African lions. Adult males weigh 160 to 190 kg (350 to 420 lb), while females weigh 110 to 120 kg (240 to 260 lb). The height at the shoulders is about 3.5 ft (110 cm).

The recorded flesh measurements of two lions in Gir Forest, by Colonel Fenton and Count Scheibler, were head-and-body measurements of 6 ft 6 in (198 cm) each, with tail-lengths of 2 ft 11 in (89 cm) and 2 ft 7 in (79 cm), and total lengths of 9 ft 5 in (287 cm) and 9 ft 3 in (282 cm), respectively. The record total length of a male Asiatic lion is 2.92 m (115 in) including the tail (Sinha, 1987).

Adult male Asiatic lion at the Gir Forest.

Though the last lion of what is now Pakistan was thought to have been killed near Kot Diji in Sindh Province in 1810, a British Admiral, while traveling on a train accompanied by two others, reportedly saw a maneless lion eating a goat near Quetta in 1935. He said "It was a large lion, very stocky, light tawny in colour, and I may say that no one of us three had the slightest doubt of what we had seen until, on our arrival at Quetta, many officers expressed doubts as to its identity, or to the possibility of there being a lion in the district."

The fur ranges in colour from ruddy-tawny, heavily speckled with black, to sandy or buff-ish-grey, sometimes with a silvery sheen in certain lights. Males have only moderate mane growth at the top of the head, so that their ears are always visible. The mane is scanty on the cheeks and throat with where it is only 4 in (10 cm) long. About half of Asiatic lion skulls from the Gir forest have divided infraorbital foramina, whereas in African lions, there is only one foramen on either side. The sagittal crest is more strongly developed, and the post-orbital area is shorter than in African lion. Skull length in adult males ranges from 330 to 340 mm (13 to 13 in), and in females from 292 to 302 mm (11.5 to 11.9 in).

Compared to populations of African lions, the Asiatic lion revealed a diminished amount of genetic variation, which may result from a founder effect in the recent history of the remnant population in the Gir Forest.

Distribution and Habitat

The Gir National Park and Wildlife Sanctuary in Western Gujarat is the only habitat for the Asiatic lion where an area of 1,412.1 km^2 (545.2 sq mi) was declared as a sanctuary for their conservation in 1965. Later, a national park covering an area of 258.71 km^2 (99.89 sq mi) was established where no human activity is allowed. In the surrounding sanctuary only Maldharis have the right to graze their livestock.

Asiatic lion at Gir Forest National Park.

The population recovered from the brink of extinction to 411 individuals in 2010. Lions occupy remnant forest habitats in the two hill systems of Gir and Girnar that comprise Gujarat's largest tracts of dry deciduous forest, thorny forest and savanna and provide valuable habitat for a diverse flora and fauna. Five protected areas currently exist to protect the Asiatic lion: Gir Sanctuary, Gir National Park, Pania Sanctuary, Mitiyala Sanctuary, and Girnar Sanctuary. The first three protected areas form the Gir Conservation Area, a 1,452 km² (561 sq mi) forest block that represents the core habitat of the Asiatic lions. The other two sanctuaries, Mitiyala and Girnar, protect satellite areas within dispersal distance of the Gir Conservation Area. An additional sanctuary is being established in the nearby Barda forest to serve as an alternative home for Gir lions. The drier eastern part is vegetated with acacia thorn savanna and receives about 650 mm (26 in) annual rainfall; rainfall in the west is higher at about 1,000 mm (39 in) per year.

As of 2010, approximately 105 lions, comprising 35 males, 35 females, 19 subadults, and 16 cubs existed outside the Gir forest, representing a full quarter of the entire lion population. The increase in satellite lion populations may represent the saturation of the lion population in the Gir forest and subsequent dispersal by sub-adults compelled to search for new territories outside their natal pride. Over the past two decades, these satellite areas became established, self-sustaining populations as evidenced by the presence of cubs since 1995.

As of May 2015, the lion population was estimated at 523 individuals, comprising 268 individuals in the Junagadh district, 44 in the Gir Somnath District, 174 in the Amreli District and 37 in the Bhavnagar District.

Former Range

The Asiatic lion used to live in West, South and Central regions of Asia and in Eastern Europe in historic times. Now the population of the lions currently exists in Western India's Gir Forest National Park. The type specimen of the Asiatic lion was first described from Persia in 1826, followed by descriptions of specimens from Hariana and

Basra. Asiatic lions formerly occurred in Persia, Arabia, Palestine, Mesopotamia and Baluchistan. Lions inhabited the southern part of the Balkan peninsula up to Macedonia and probably the Danube River, but disappeared in Greece around the first century. In the Trans-Caucasus, they were known since the Holocene and became extinct in the 10th century. Lions survived in regions adjoining Mesopotamia and Syria until the middle of the 19th century, and were still sighted in the upper reaches of the Euphrates River in the early 1870s. They were widespread in Iran, but in the 1870s were sighted only on the western slopes of the Zagros Mountains and in the forest regions south of Shiraz.

Asiatic lion depicted on a hunting scene (7th century BC, Nineveh)

Reginald Innes Pocock suggested that their restricted distribution in India, compared to that of Bengal tigers, indicated that they were comparatively recent immigrants that came to India through Persia and Baluchistan, before man could limit their movement or presence throughout India, and not that Bengal tigers played a role in their near extinction, whether significant or small, unlike what some people thought. Just as they co-existed with Bengal tigers in parts of India, or, in the extended, modern sense, the Subcontinent, they occurred in areas that had Caspian tigers, like northern Persia and the Trans-Caucasus, before man extirpated either lions or tigers in any of these places.

The advent of firearms led to their extinction over large areas. By the late 19th century, Asiatic lions had become extinct in the area that is modern day Turkey. In Iran, lions served as the national emblem and appeared on the country's flag. Some of the last lions were sighted in 1941 between Shiraz and Jahrom in the Fars Province. In 1944, the corpse of a lioness was found on the banks of the Karun river in Iran's Khuzestan Province.

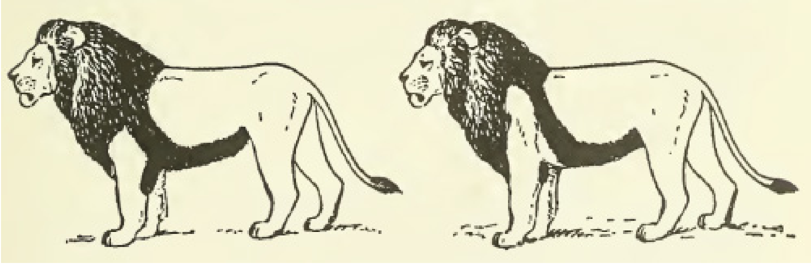
In India, Asiatic lions once ranged to the state of Bengal, but declined under heavy hunting pressure. In the early 19th century, they were found in north-western and central India in Hariana, Khandesh (in modern-day Maharashtra), Rajasthan, Sindh, and eastward as far as Palamu and Rewa, Madhya Pradesh. Heavy hunting by British colonial officers and their Indian vassal rulers led to a steady and marked decline of lion numbers in the country. Asiatic lions were exterminated in Palamau by 1814, in Baroda, Haryana and Ahmedabad in the 1830s, in Kot Diji and Damoh in the 1840s. During the Indian Rebellion of 1857, a British officer shot 300 lions. The last lions of Gwalior and Rewah were shot in the 1860s. By 1880 no lion survived in Guna, Deesa and Palanpur, and only about a dozen lions were left in the Junagadh district. By the turn of the century, they were confined to the Gir Forest and protected by the Nawab of Junagadh in his private hunting grounds.

One lion was killed near Allahabad in 1866. The last lion of Mount Abu was spotted in 1872.

Ecology and Behaviour

Asiatic lions live in prides. Mean pride size, measured by the number of adult females, tends to be smaller than for African lions: most Gir prides contain just two adult females, with the largest having five. Coalitions of males defend home ranges containing one or more groups of females; but, unlike African lions, Gir males generally associate with their pride females only when mating or on a large kill. A lesser degree of sociability in the Gir lions may be a function of the smaller prey available to them: the most commonly taken species (45% of known kills), the chital, weighs only around 50 kg (110 lb).

Male Asiatic lion resting under tree cover.



Comparative illustration of typical Asiatic lion mane types.

Male Asiatic lion after a fight.

In general, lions prefer large prey species within a weight range of 190 to 550 kg (420 to 1,210 lb) irrespective of their availability. Yet they predominately take prey substantially smaller than this, reflecting their opportunistic hunting behaviour. Within this range, they prefer species that weigh 350 kg (770 lb), which is much larger than the largest recorded weight of lion. The group hunting strategy of lions enables exceptionally large prey items to be taken. Hunting success in lions is influenced by hunting-group size and composition, the hunting method used and by environmental factors such as grass and shrub cover, time of day, moon presence and terrain. Domestic cattle have historically been a major component of the Gir lions' diet.

Asiatic Lion Cub

In 1974, the Forest Department estimated the wild ungulate population to be 9,650 individuals. This population grew consistently in subsequent surveys, reaching 31,490 in 1990 and 64,850 in 2010, consisting of 52,490 spotted deer, 4,440 wild boar, 4,000 sambar, 2,890 blue bull, 740 chinkara, and 290 four-horned antelope. Thus, in the past four decades, the population of wild ungulates increased by over ten times. In contrast, populations of domestic buffalo and cattle declined following resettlement, largely due to direct removal of resident livestock from the Gir Conservation Area. The population of 24,250 resident animals in the 1970s declined to 12,500 in the mid-1980s, but increased to 23,440 animals in 2010. Following changes in both predator and prey communities, Asiatic lions shifted their predation patterns. Today, very few livestock kills occur within the sanctuary, and instead most occur in peripheral villages. In and around the Gir forest, depredation records indicate that lions killed on average 2023 livestock annually between 2005 and 2009, and an additional 696 individuals in satellite areas.

Cases of Predation or Attacks on Humans

On the 18th of July 2012, in the Village of Nagreshi, Taluka of Jafrabad, District of Amreli, Gujarat, a lion dragged a 50-year-old man from the veranda of his house and killed him, 50–60 km (31–37 miles) from the sanctuary of Gir. This was the second attack in the area, six months after a 25-year-old man was attacked and killed in Dhodadar.

Threats

The Asiatic lion currently exists as a single subpopulation, and is thus vulnerable to extinction from unpredictable events, such as an epidemic or large forest fire. There are indications of poaching incidents in recent years. There are reports that organized gangs have switched attention from tigers to these lions. There have also been a number of drowning incidents after lions fell into wells.

Prior to the resettlement of Maldharis, the Gir forest was heavily degraded and used by livestock, which competed with and restricted the population sizes of native ungulates. Various studies reveal tremendous habitat recovery and increases in wild ungulate populations following the Maldhari resettlement during the last four decades. Farmers on the periphery of the Gir Forest frequently use crude and illegal electrical fences by powering them with high voltage overhead power lines. These are usually intended to protect their crops from nilgai, but lions and other wildlife are also killed. Nearly 20,000 open wells dug by farmers in the area for irrigation have also acted as traps, which led to many lions drowning. To counteract the problem, suggestions for walls around the wells, as well as the use of “drilled tube wells” have been made.

Conservation

Panthera leo persica is included on CITES Appendix I, and is fully protected in India.

Asiatic Lion in Lucknow Zoo

Reintroduction

In the 1950s, biologists advised the government to re-establish at least one wild population in the Asiatic lion’s former range in order to ensure the population’s reproductive health and to prevent it from being affected by an outbreak of an epidemic. In 1956, the Indian Board for Wildlife accepted a proposal by the Uttar Pradesh government to establish a new sanctuary for the envisaged reintroduction : the *Chandraprabha Wildlife Sanctuary* covering 96 km² (37 sq mi) in eastern Uttar Pradesh where climate, terrain and vegetation is similar to the conditions in the Gir Forest. In 1957, one male and two female wild-caught Asiatic lions were set free in the sanctuary. This population comprised 11 animals in 1965, which all disappeared thereafter.

The Asiatic Lions at Sanjay Gandhi National Park, Borivali, Mumbai Lion Safari, India

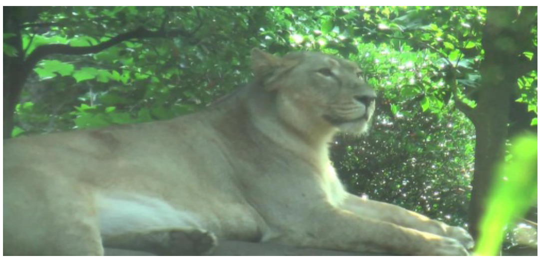
The Asiatic Lion Reintroduction Project to find an alternative habitat for reintroducing Asiatic lions was pursued in the early 1990s. Biologists from the Wildlife Institute of India assessed several potential translocation sites for their suitability regarding existing prey population and habitat conditions. The Palpur-Kuno Wildlife Sanctuary in northern Madhya Pradesh was ranked as the most promising location, followed by the Sita Mata Wildlife Sanctuary and the Darrah National Park. Until 2000, 1,100 families from 16 villages had been resettled from the Palpur-Kuno Wildlife Sanctuary, and another 500 families from eight villages envisaged to be resettled. With this resettlement scheme the protected area was expanded by 345 km² (133 sq mi).

Gujarat state officials resisted the relocation, since it would make the Gir Sanctuary lose its status as the world's only home of the Asiatic lion. Gujarat has raised a number of objections to the proposal, and the matter is now before the Indian Supreme Court. In April 2013, the Indian Supreme Court ordered the Gujarat state to send some of their Gir lions to Madhya Pradesh to establish a second population there. The court has given wildlife authorities six months to complete the transfer. The number of lions and which ones to be transported will be decided at a later date.

In Captivity

Until the late 1990s, captive Asiatic lions in Indian zoos were haphazardly interbred with African lions confiscated from circuses, leading to genetic pollution in the captive Asiatic lion stock. Once discovered, this led to the complete shutdown of the European and American endangered species breeding programs for Asiatic lions, as its founder animals were captive-bred Asiatic lions originally imported from India and were ascertained to be intraspecific hybrids of African and Asian lions. In North American zoos, several Indian-African lion crosses were inadvertently bred, and researchers noted that "the fecundity, reproductive success, and spermatozoal development improved dramatically."

When kept in zoos in colder climates, lions usually develop stronger manes as shown by this male at Chester Zoo, UK.



A captive Asiatic lioness resting and yawning.

DNA fingerprinting studies of Asiatic lions have helped in identifying individuals with high genetic variability, which can be used for conservation breeding programs.

In 2006, the Central Zoo Authority of India stopped breeding Indian-African cross lions stating that "hybrid lions have no conservation value and it is not worth to spend resources on them". Now only pure native Asiatic lions are bred in India.

The Asiatic lion International Studbook was initiated in 1977, followed in 1983 by the North American Species Survival Plan (SSP). The North American population of captive Asiatic lions was composed of descendants of five founder lions, three of which were pure Asian and two were African or African-Asian hybrids. The lions kept in the framework of the SSP consisted of animals with high inbreeding coefficients.

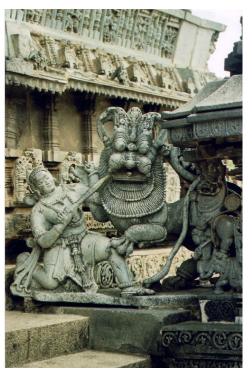
In the early 1990s, three European zoos imported pure Asiatic lions from India: the London Zoo obtained two pairs; the Zürich Zoologischer Garten one pair; and the Helsinki Zoo one male and two females. In 1994, the European Endangered Species Programme (EEP) for Asiatic lions was initiated. The European Association of Zoos and Aquaria (EAZA) published the first European Studbook in 1999. By 2005, there were 80 Asiatic lions kept in the EEP — the only captive population outside of India.

There are now over 100 Asiatic lions in the EEP. The SSP did not yet resume; pure-bred Asiatic lions are needed to form a new founder population for breeding in American zoos.

In Mythology, Religion and Art

Hindu Goddess Durga has an Asiatic lion as her *vahanam* or divine mount

A page from *Kelileh o Demneh* dated 1429, from Herat, a Persian translation of the ancient Indian *Panchatantra*.



Emblem of the Hoysala Empire in Ancient India, depicting Sala fighting the Lion.

Dirham coin of Kaykhusraw II, Sivas, AH 638/AD 1240-1

- The Sanskrit word for lion is si□ha, which also signifies the *Leo* of the Zodiac.
- *Narasimha* (*Narasingh* or *Narasinga* – man-lion) is described as an incarnation (avatar) of Vishnu within the Puranic texts of Hinduism and is worshiped as “Lion God”. Thus, Asiatic lions are considered sacred by all Hindus in India.
- A lion-faced *dakini* also appears in Hinduism and Tibetan Buddhism. The Hindu deity is known as *Narasimha* and the Tibetan Buddhist form is known as *Si□hamukhā* in Sanskrit and *Senge Dongma* (Wyl. *seng ge gdong ma*) in Tibetan.
- The lion is found on numerous flags and coats of arms all across Asia and Europe, and also appears on the Emblem of India and on the flag of Sri Lanka.
- *Singhāsana* meaning *seat of a lion* is the traditional Sanskrit name for the throne of a Hindu kingdom in India and Sinhalese kingdom in Sri Lanka since antiquity.
- The surnames Singh, Singha and Sinha are related to the Prakrit word *si□gha* and Sanskrit word *si□h□* which refer to lions, tigers and leopards. These are common Sikh and Hindu surnames dating back over 2000 years to ancient India. They originally only used by Rajputs, a Hindu *kshatriya* or military caste in India since the seventh century. After the birth of the Khalsa brotherhood in 1699, the Sikhs adopted the name “Singh” at the direction of Guru Gobind Singh. As this name was associated with higher classes and royalty, this action was to combat the prevalent caste system and discrimination by last name. Along with millions of Hindu Rajputs today, it is also used by up to 10 million Sikhs worldwide.
- The Sinhalese people are the majority ethnic group of Sri Lanka. The name Sinhala translates to “lion’s blood” or “lion people” and refers to the myths regarding the descent of the legendary founder of the Sinhalese people 2500 years ago, Prince Vijaya, who is said to have migrated from *Singhapur* (Simhapura or Singur).
- The words “singha” or “singham” meaning “courageous lion” are used as an ending of many surnames, such as “Weerasingha” used by the Sinhala people, and “Veerasingham” used by the Tamil people.
- The name *Sinhala* comes from the belief that Vijaya’s paternal grandfather was a lion. An alternative theory places *Singhapur* in modern Sihor, which happens to be close to the Gir Sanctuary.
- The island nation of Singapore (*Singapura*) derives its name from the Malay words *singa* (lion) and *pura* (city), which in turn is from the Sanskrit *si□ha*

and *pura*. According to the Malay Annals, this name was given by a 14th-century Sumatran Malay prince named Sang Nila Utama, who, on alighting the island after a thunderstorm, spotted an auspicious beast on shore that his chief minister identified as an Asiatic lion. Recent studies of Singapore indicate lions have never lived there, and the animal seen by Sang Nila Utama was likely a tiger. Tigers that inhabit the Malay Peninsula nearby are called *Panthera tigris jacksoni* or *Panthera tigris corbetti*, whereas tigers that inhabit the nearby Indonesian island of Sumatra are called *Panthera tigris sumatrae*.

- The lion makes repeated appearances in the Bible, most notably as having fought Samson in the Book of Judges.
- The lion is the basis of the lion dances that form part of the traditional Chinese New Year celebrations, and of similar customs in other Asian countries.
- Chinese guardian lions depicted in Chinese art were modelled on the basis of lions found in Indian temples.
- Buddhist monks, or possibly traders, possibly brought descriptions of sculpted lions guarding the entry to temples to China. Chinese sculptors then used the description to model “Fo-Lions” (*Fo* 佛 being Chinese for Buddha) temple statues after native dogs (possibly the Tibetan Mastiff) by adding a shaggy mane. Depictions of these “Fo-lions” have been found in Chinese religious art as early as 208 BC.
- The Tibetan Snow Lion (Tibetan: གངས་སེང་གེ་; Wylie: *gangs seng ge*) is a mythical animal of Tibet. It symbolizes fearlessness, unconditional cheerfulness, the eastern quadrant and the element of Earth. It is said to range over mountains, and is commonly pictured as being white with a turquoise mane. Two Snow Lions appear on the flag of Tibet.
- The symbol of the lion is closely tied to the Persian people. Achaemenid kings were known to carry the symbol of the lion on their thrones and garments. The Lion and Sun, or *Shir-va-Khorshid*, is one of the most prominent symbols of Iran. It dates back to the Safavid dynasty, and was used on the flag of Iran until 1979.
- The Nemean lion of pre-literate Greek myth is associated with the Labours of Herakles.
- Scythian art from Ukraine dated to the 4th century BC depicts Scythians hunting very realistically portrayed lions.

Bonobo

The bonobo (*Pan paniscus*), formerly called the pygmy chimpanzee and less often, the dwarf or gracile chimpanzee, is an endangered great ape and one of the two species making up the genus *Pan*; the other is *Pan troglodytes*, or the common chimpanzee. Although the name "chimpanzee" is sometimes used to refer to both species together, it is usually understood as referring to the common chimpanzee, whereas *Pan paniscus* is usually referred to as the bonobo.

The bonobo is distinguished by relatively long legs, pink lips, dark face and tail-tuft through adulthood, and parted long hair on its head. The bonobo is found in a 500,000 km^2 (190,000 sq mi) area of the Congo Basin in the Democratic Republic of the Congo, Central Africa. The species is omnivorous and inhabits primary and secondary forests, including seasonally inundated swamp forests. Political instability in the region and the timidity of bonobos has meant there has been relatively little field work done observing the species in its natural habitat.

Along with the common chimpanzee, the bonobo is the closest extant relative to humans. Because the two species are not proficient swimmers, the formation of the Congo River 1.5–2 million years ago possibly led to the speciation of the bonobo. Bonobos live south of the river, and thereby were separated from the ancestors of the common chimpanzee, which live north of the river. There is no concrete data on population numbers, but the estimate is between 29,500 and 50,000 individuals. The species is listed as Endangered on the IUCN Red List and is threatened by habitat destruction and human population growth and movement, though commercial poaching is the most prominent threat. They typically live 40 years in captivity; their lifespan in the wild is unknown. As of June 2016 a total of 119 live in zoos across Europe; 65 distributed between six different German zoos, and a further 54 in zoos in Belgium, France, the Netherlands and England.

Etymology

Despite the alternative common name "pygmy chimpanzee", the bonobo is not especially diminutive when compared to the common chimpanzee. "Pygmy" may instead refer to the pygmy peoples who live in the same area. The name "bonobo" first appeared in 1954, when Eduard Paul Tratz and Heinz Heck proposed it as a new and separate generic term for pygmy chimpanzees. The name is thought to be a misspelling on a shipping crate from the town of Bolobo on the Congo River, which was associated with the collection of chimps in the 1920s. The term has also been reported as being a word for "ancestor" in an extinct Bantu language.

Evolutionary History

Fossils

Fossils of *Pan* species were not described until 2005. Existing chimpanzee populations in West and Central Africa do not overlap with the major human fossil sites in East Africa. However, *Pan* fossils have now been reported from Kenya. This would indicate that both humans and members of the *Pan* clade were present in the East African Rift

Valley during the Middle Pleistocene. According to A. Zihlman, bonobo body proportions closely resemble those of *Australopithecus*, leading evolutionary biologists like Jeremy Griffith to suggest that bonobos may be a living example of our distant human ancestors.

Taxonomy and Phylogeny

German anatomist Ernst Schwarz is credited with being the first Westerner to recognise the bonobo as being distinctive, in 1928, based on his analysis of a skull in the Tervuren museum in Belgium that previously had been thought to have belonged to a juvenile chimpanzee. Schwarz published his findings in 1929. In 1933, American anatomist Harold Coolidge offered a more detailed description of the bonobo, and elevated it to species status. The American psychologist and primatologist Robert Yerkes was also one of the first scientists to notice major differences between bonobos and chimpanzees. These were first discussed in detail in a study by Eduard Paul Tratz and Heinz Heck published in the early 1950s.

The first official publication of the sequencing and assembly of the bonobo genome became publicly available in June 2012. It was deposited with the International Nucleotide Sequence Database Collaboration (DDBJ/EMBL/GenBank) under the EMBL accession number AJFE01000000 after a previous analysis by the National Human Genome Research Institute confirmed that the bonobo genome is about 0.4% divergent from the chimpanzee genome. In addition, as of 2011 Svante Pääbo's group at the *Max Planck Institute for Evolutionary Anthropology* were sequencing the genome of a female bonobo from the Leipzig zoo.

Initial genetic studies characterised the DNA of chimpanzees and bonobos as being 98% to 99.4% identical to that of *Homo sapiens*. Later studies showed that chimpanzees and bonobos are more closely related to humans than to gorillas. In the crucial *Nature* paper reporting on initial genome comparisons, researchers identified 35 million single-nucleotide changes, five million insertion or deletion events, and a number of chromosomal rearrangements which constituted the genetic differences between the two *Pan* species and humans, covering 98% of the same genes. While many of these analyses have been performed on the common chimpanzee rather than the bonobo, the differences between the two *Pan* species are unlikely to be substantial enough to affect the *Pan-Homo* comparison significantly.

There still is controversy, however. Scientists such as Jared Diamond in *The Third Chimpanzee*, and Morris Goodman of Wayne State University in Detroit suggest that the bonobo and common chimpanzee are so closely related to humans that their genus name also should be classified with the human genus *Homo*: *Homo paniscus*, *Homo sylvestris*, or *Homo arboreus*. An alternative philosophy suggests that the term *Homo sapiens* is the misnomer rather, and that humans should be reclassified as *Pan sapiens*, though this would violate the Principle of Priority, as *Homo* was named before *Pan*

(1758 for the former, 1816 for the latter). In either case, a name change of the genus would have implications on the taxonomy of extinct species closely related to humans, including *Australopithecus*. The current line between *Homo* and non-*Homo* species is drawn about 2.5 million years ago, and chimpanzee and human ancestry converge only about 7 million years ago, nearly three times longer.

DNA evidence suggests the bonobo and common chimpanzee species effectively separated from each other fewer than one million years ago. The *Pan* line split from the last common ancestor shared with humans approximately six to seven million years ago. Because no species other than *Homo sapiens* has survived from the human line of that branching, both *Pan* species are the closest living relatives of humans and cladistically are equally close to humans. The recent genome data confirms the genetic equidistance.

Description

The bonobo is commonly considered to be more gracile than the common chimpanzee. Although large male chimpanzees can exceed any bonobo in bulk and weight, the two species actually broadly overlap in body size. Adult female bonobos are somewhat smaller than adult males. Body mass in males ranges from 34 to 60 kg (75 to 132 lb), against an average of 30 kg (66 lb) in females. The total length of bonobos (from the nose to the rump while on all fours) is 70 to 83 cm (28 to 33 in). When adult bonobos and chimpanzees stand up on their legs, they can both attain a height of 115 cm (45 in). The bonobo's head is relatively smaller than that of the common chimpanzee with less prominent brow ridges above the eyes. It has a black face with pink lips, small ears, wide nostrils, and long hair on its head that forms a parting. Females have slightly more prominent breasts, in contrast to the flat breasts of other female apes, although not so prominent as those of humans. The bonobo also has a slim upper body, narrow shoulders, thin neck, and long legs when compared to the common chimpanzee.

Bonobos Kanzi (C) and Panbanisha (R) with Sue Savage-Rumbaugh and the outdoor symbols "keyboard." Credit: W. H. Calvin 2006

Bonobos are both terrestrial and arboreal. Most ground locomotion is characterized by quadrupedal knuckle walking. Bipedal walking has been recorded as less than 1% of terrestrial locomotion in the wild, a figure that decreased with habituation, while in captivity there is a wide variation. Bipedal walking in captivity, as a percentage of bipedal plus quadrupedal locomotion bouts, has been observed from 3.9% for spontaneous bouts to nearly 19% when abundant food is provided. These physical characteristics and its posture give the bonobo an appearance more closely resembling that of humans than that of the common chimpanzee. The bonobo also has highly individuated facial features, as humans do, so that one individual may look significantly different from another, a characteristic adapted for visual facial recognition in social interaction.

Multivariate analysis has shown bonobos are more neotenized than the common chimpanzee, taking into account such features as the proportionately long torso length of the bonobo. Other researchers challenged this conclusion.

Behavior

General

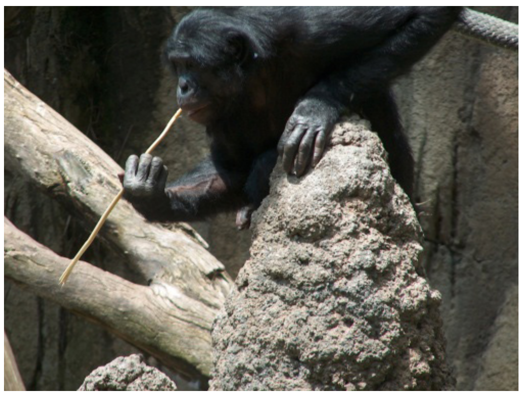
Primatologist Frans de Waal states bonobos are capable of altruism, compassion, empathy, kindness, patience, and sensitivity, and described "bonobo society" as a "gynecocracy". Primatologists who have studied bonobos in the wild have documented a wide range of behaviors, including aggressive behavior and more cyclic sexual behavior similar to chimpanzees, even though the fact remains that bonobos show more sexual behavior in a greater variety of relationships. An analysis of female bonding among wild bonobos by Takeshi Furuichi stresses female sexuality and shows how female bonobos spend much more time in estrus than female chimpanzees. Some primatologists have argued that de Waal's data reflect only the behavior of captive bonobos, suggesting that wild bonobos show levels of aggression closer to what is found among chimpanzees. De Waal has responded that the contrast in temperament between bonobos and chimpanzees observed in captivity is meaningful, because it controls for the influence of environment. The two species behave quite differently even if kept under identical conditions. A 2014 study also found bonobos to be less aggressive than chimpanzees, particularly eastern chimpanzees. The authors argued that the relative peacefulness of western chimpanzees and bonobos was primarily due to ecological factors.

Social Behavior

Most studies indicate that females have a higher social status in bonobo society. Aggressive encounters between males and females are rare, and males are tolerant of infants and juveniles. A male derives his status from the status of his mother. The mother–son bond often stays strong and continues throughout life. While social hierarchies do exist, rank plays a less prominent role than in other primate societies.

Because of the promiscuous mating behavior of female bonobos, a male cannot be sure which offspring are his. As a result, the entirety of parental care in bonobos is assumed by the mothers.

Bonobos are very social.



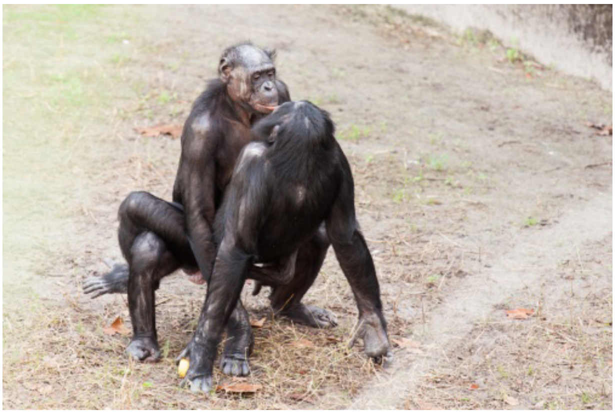
Bonobo searching for termites

Bonobo party size tends to vary because the groups exhibit a fission–fusion pattern. A community of approximately 100 will split into small groups during the day while looking for food, and then will come back together to sleep. They sleep in nests that they construct in trees.

Sociosexual Behaviour

Sexual activity generally plays a major role in bonobo society, being used as what some scientists perceive as a greeting, a means of forming social bonds, a means of conflict resolution, and postconflict reconciliation. Bonobos are the only non-human animal to have been observed engaging in tongue kissing, and oral sex. Bonobos and humans are the only primates to typically engage in face-to-face genital sex, although a pair of western gorillas has been photographed in this position.

Bonobos do not form permanent monogamous sexual relationships with individual partners. They also do not seem to discriminate in their sexual behavior by sex or age, with the possible exception of abstaining from sexual activity between mothers and their adult sons. When bonobos come upon a new food source or feeding ground, the increased excitement will usually lead to communal sexual activity, presumably decreasing tension and encouraging peaceful feeding. This quality is also described by Dr. Susan Block as "The Bonobo Way" in her book of the same title "The Bonobo Way: The Evolution of Peace Through Pleasure".



Bonobos mating, Jacksonville Zoo and Gardens.

Bonobo clitorises are larger and more externalized than in most mammals; while the weight of a young adolescent female bonobo "is maybe half" that of a human teenager, she has a clitoris that is "three times bigger than the human equivalent, and visible enough to waggle unmistakably as she walks". In scientific literature, the female–female behavior of bonobos pressing genitals together is often referred to as genito-genital (GG) rubbing, which is the non-human analogue of tribadism, engaged in by human females. This sexual activity happens within the immediate female bonobo community and sometimes outside of it. Ethologist Jonathan Balcombe stated that female bonobos rub their clitorises together rapidly for ten to twenty seconds, and this behavior, "which may be repeated in rapid succession, is usually accompanied by grinding, shrieking, and clitoral engorgement"; he added that it is estimated that they engage in this practice "about once every two hours" on average. Because bonobos occasionally copulate face-to-face, "evolutionary biologist Marlene Zuk has suggested that the position of the clitoris in bonobos and some other primates has evolved to maximize stimulation during sexual intercourse". On the other hand, the frequency of face-to-face mating observed in zoos and sanctuaries is not reflected in the wild, and thus may be an artifact of captivity. The position of the clitoris may alternatively permit GG-rubbings, which has been hypothesized to function as a means for female bonobos to evaluate their intrasocial relationships.

Bonobo males occasionally engage in various forms of male–male genital behavior, which is the non-human analogue of frotting, engaged in by human males. In one form, two bonobo males hang from a tree limb face-to-face while penis fencing. This also may occur when two males rub their penises together while in face-to-face position. Another form of genital interaction (rump rubbing) occurs to express reconciliation between two males after a conflict, when they stand back-to-back and rub their scrotal sacs together. Takayoshi Kano observed similar practices among bonobos in the natural habitat.

Group of bonobos

More often than the males, female bonobos engage in mutual genital behavior, possibly to bond socially with each other, thus forming a female nucleus of bonobo society. The bonding among females enables them to dominate most of the males. Although male bonobos are individually stronger, they cannot stand alone against a united group of females. Adolescent females often leave their native community to join another community. This migration mixes the bonobo gene pools, providing genetic diversity. Sexual bonding with other females establishes these new females as members of the group.

Bonobo reproductive rates are no higher than those of the common chimpanzee. During oestrus, females undergo a swelling of the perineal tissue lasting 10 to 20 days. Most matings occur during the maximum swelling. The gestation period is on average 240 days. Postpartum amenorrhea (absence of menstruation) lasts less than one year and a female may resume external signs of oestrus within a year of giving birth, though the female is probably not fertile at this point. Female bonobos carry and nurse their young for four years and give birth on average every 4.6 years. Compared to common chimpanzees, bonobo females resume the genital swelling cycle much sooner after giving birth, enabling them to rejoin the sexual activities of their society. Also, bonobo females which are sterile or too young to reproduce still engage in sexual activity. Adult male bonobos have sex with infants. Frans de Waal, an ethologist who has studied bonobos, remarked, “A lot of the things we see, like pedophilia and homosexuality, may be leftovers that some now consider unacceptable in our particular society.”

It is unknown how the bonobo avoids simian immunodeficiency virus (SIV) and its effects.

Diet

The bonobo is an omnivorous frugivore; 57% of its diet is fruit, but this is supplemented with leaves, honey, eggs, meat from small vertebrates such as anomalures, flying squirrels and duikers, and invertebrates. In some instances, bonobos have been shown to consume lower-order primates. Some claim bonobos have also been known to practise cannibalism in captivity, a claim disputed by others. However, at least one confirmed report of cannibalism in the wild of a deceased infant was described in 2008.

Peacefulness

Observations in the wild indicate that the males among the related common chimpanzee communities are extraordinarily hostile to males from outside the community. Parties of males 'patrol' for the neighboring males that might be traveling alone, and attack those single males, often killing them. This does not appear to be the behavior of bonobo males or females, which seem to prefer sexual contact over violent confrontation with outsiders. In fact, the Japanese scientists who have spent the most time working with wild bonobos describe the species as extraordinarily peaceful, and de Waal has documented how bonobos may often resolve conflicts with sexual contact (hence the "make love, not war" characterization for the species). Between groups, social mingling may occur, in which members of different communities have sex and groom each other, behavior which is unheard of among common chimpanzees. Conflict is still possible between rival groups of bonobos, but no official scientific reports of it exist. The ranges of bonobos and chimpanzees are separated by the Congo River, with bonobos living to the south of it, and chimpanzees to the north. It has been hypothesized that bonobos are able to live a more peaceful lifestyle in part because of an abundance of nutritious vegetation in their natural habitat, allowing them to travel and forage in large parties.

Bonobo (*Pan paniscus*) mother and infant at Lola ya Bonobo

Recent studies show that there are significant brain differences between bonobos and chimps. The brain anatomy of bonobos has more developed and larger regions assumed to be vital for feeling empathy, sensing distress in others and feeling anxiety, which makes them less aggressive and more empathic than their close relatives. They also have a thick connection between the amygdala, an important area that can spark aggression, and the ventral anterior cingulate cortex, which helps control impulses. This thicker connection may make them better at regulating their emotional impulses and behavior.

Bonobo society is dominated by females, and severing the lifelong alliance between mothers and their male offspring may make them vulnerable to female aggression. De Waal has warned of the danger of romanticizing bonobos: "All animals are competitive by nature and cooperative only under specific circumstances" and that "when first writing about their behaviour, I spoke of 'sex for peace' precisely because bonobos had plenty of conflicts. There would obviously be no need for peacemaking if they lived in perfect harmony."

Surbeck and Hohmann showed in 2008 that bonobos sometimes do hunt monkey species. Five incidents were observed in a group of bonobos in Salonga National Park, which seemed to reflect deliberate cooperative hunting. On three occasions, the hunt was successful, and infant monkeys were captured and eaten.

Similarity to Humans

Bonobos are capable of passing the mirror-recognition test for self-awareness, as are all great apes. They communicate primarily through vocal means, although the meanings of their vocalizations are not currently known. However, most humans do understand their facial expressions and some of their natural hand gestures, such as their invitation to play. The communication system of wild bonobos includes a characteristic that was earlier only known in humans: bonobos use the same call to mean different things in different situations, and the other bonobos have to take the context into account when determining the meaning. Two bonobos at the Great Ape Trust, Kanzi and Panbanisha, have been taught how to communicate using a keyboard labeled with lexigrams (geometric symbols) and they can respond to spoken sentences. Kanzi's vocabulary consists of more than 500 English words, and he has comprehension of around 3,000 spoken English words. Kanzi is also known for learning by observing people trying to teach his mother; Kanzi started doing the tasks that his mother was taught just by watching, some of which his mother had failed to learn. Some, such as philosopher and bioethicist Peter Singer, argue that these results qualify them for "rights to survival and life" rights that humans theoretically accord to all persons. Afterwards Kanzi was also taught how to use and create stone tools in 1990. Then, with-in 3 years, three researchers Kathy Schick, Nicholas Toth and Gary Garufi wanted to test Kanzi's knapping skills. Though Kanzi was able to form flake technology, he did not create it the way they expected. Unlike the way hominids did it, where they held the core in one hand and knapped it with the other, Kanzi threw the cobble against a hard surface or against another cobble. This allowed him to produce a larger force to initiate a fracture as opposed to knapping it in his hands.

As in other great apes and humans, third party affiliation toward the victim – the affinitive contact made toward the recipient of an aggression by a group member other than the aggressor – is present in bonobos. A 2013 study found that both the affiliation spontaneously offered by a bystander to the victim and the affiliation requested by the victim (solicited affiliation) can reduce the probability of further aggression by group members on the victim (this fact supporting the *Victim-Protection Hypothesis*).

Yet, only spontaneous affiliation reduced victim anxiety – measured via self-scratching rates – thus suggesting not only that non-solicited affiliation has a consolatory function but also that the spontaneous gesture – more than the protection itself – works in calming the distressed subject. The authors hypothesize that the victim may perceive the motivational autonomy of the bystander, who does not require an invitation to provide post-conflict affinitive contact. Moreover, spontaneous – but not solicited – third party affiliation was affected by the bond between consoler and victim (this supporting the *Consolation Hypothesis*). Importantly, spontaneous affiliation followed the empathic gradient described for humans, being mostly offered to kin, then friends, then acquaintances (these categories having been determined using affiliation rates between individuals). Hence, consolation in the bonobo may be an empathy-based phenomenon.

Instances in which non-human primates have expressed joy have been reported. One study analyzed and recorded sounds made by human infants and bonobos when they were tickled. Although the bonobos' laugh was at a higher frequency, the laugh was found to follow a spectrographic pattern similar to that of human babies.

Distribution and Habitat

Bonobos are found only south of the Congo River and north of the Kasai River (a tributary of the Congo), in the humid forests of the Democratic Republic of Congo of central Africa. Ernst Schwarz's 1927 paper "*Le Chimpanzé de la Rive Gauche du Congo*", announcing his discovery, has been read as an association between the Parisian Left Bank and the left bank of the Congo River; the bohemian culture in Paris, and an unconventional ape in the Congo.

Conservation Status

The IUCN Red List classifies bonobos as an endangered species, with conservative population estimates ranging from 29,500 to 50,000 individuals. Major threats to bonobo populations include habitat loss and hunting for bushmeat, the latter activity having increased dramatically during the first and second Congo wars in the Democratic Republic of Congo due to the presence of heavily armed militias even in remote "protected" areas such as Salonga National Park. This is part of a more general trend of ape extinction.

As the bonobos' habitat is shared with people, the ultimate success of conservation efforts will rely on local and community involvement. The issue of parks versus people is salient in the Cuvette Centrale the bonobos' range. There is strong local and broad-based Congolese resistance to establishing national parks, as indigenous communities have often been driven from their forest homes by the establishment of parks. In Salonga National Park, the only national park in the bonobo habitat, there is no local involvement, and surveys undertaken since 2000 indicate the bonobo, the African forest elephant, and other species have been severely devastated by poachers and the thriving bushmeat trade. In contrast, areas exist where the bonobo and biodiversity still thrive without any established parks, due to the indigenous beliefs and taboos against killing bonobos.

During the wars in the 1990s, researchers and international non-governmental organizations (NGOs) were driven out of the bonobo habitat. In 2002, the Bonobo Conservation Initiative initiated the Bonobo Peace Forest Project supported by the Global Conservation Fund of Conservation International and in cooperation with national institutions, local NGOs, and local communities. The Peace Forest Project works with local communities to establish a linked constellation of community-based reserves, managed by local and indigenous people. This model, implemented mainly through DRC organizations and local communities, has helped bring about agreements to protect over 50,000 square miles (130,000 km^2) of the bonobo habitat. According to Dr. Amy Parish, the Bonobo Peace Forest "is going to be a model for conservation in the 21st century."

The port town of Basankusu is situated on the Lulonga River, at the confluence of the Lopori and Maringa Rivers, in the north of the country, making it well placed to receive and transport local goods to the cities of Mbandaka and Kinshasa. With Basankusu being the last port of substance before the wilderness of the Lopori Basin and the Lomako River——the bonobo heartland—conservation efforts for the bonobo use the town as a base.

In 1995, concern over declining numbers of bonobos in the wild led the Zoological Society of Milwaukee, in Milwaukee, Wisconsin, with contributions from bonobo scientists around the world, to publish the Action Plan for *Pan paniscus*: A Report on Free Ranging Populations and Proposals for their Preservation. The Action Plan compiles population data on bonobos from 20 years of research conducted at various sites throughout the bonobo's range. The plan identifies priority actions for bonobo conservation and serves as a reference for developing conservation programs for researchers, government officials, and donor agencies.

Acting on Action Plan recommendations, the ZSM developed the Bonobo and Congo Biodiversity Initiative. This program includes habitat and rain-forest preservation, training for Congolese nationals and conservation institutions, wildlife population assessment and monitoring, and education. The Zoological Society has conducted regional surveys within the range of the bonobo in conjunction with training Congolese researchers in survey methodology and biodiversity monitoring. The Zoological Society's initial goal was to survey Salonga National Park to determine the conservation status of the bonobo within the park and to provide financial and technical assistance to strengthen park protection. As the project has developed, the Zoological Society has become more involved in helping the Congolese living in bonobo habitat. The Zoological Society has built schools, hired teachers, provided some medicines, and started an agriculture project to help the Congolese learn to grow crops and depend less on hunting wild animals.

With grants from the United Nations, USAID, the U.S. Embassy, the World Wildlife Fund, and many other groups and individuals, the Zoological Society also has been working to:

- Survey the bonobo population and its habitat to find ways to help protect these apes
- Develop antipoaching measures to help save apes, forest elephants, and other endangered animals in Congo's Salonga National Park, a UN World Heritage site
- Provide training, literacy education, agricultural techniques, schools, equipment, and jobs for Congolese living near bonobo habitats so that they will have a vested interest in protecting the great apes – the ZSM started an agriculture project to help the Congolese learn to grow crops and depend less on hunting wild animals.
- Model small-scale conservation methods that can be used throughout Congo

Starting in 2003, the U.S. government allocated $54 million to the Congo Basin Forest Partnership. This significant investment has triggered the involvement of international NGOs to establish bases in the region and work to develop bonobo conservation programs. This initiative should improve the likelihood of bonobo survival, but its success still may depend upon building greater involvement and capability in local and indigenous communities.

The bonobo population is believed to have declined sharply in the last 30 years, though surveys have been hard to carry out in war-ravaged central Congo. Estimates range from 60,000 to fewer than 50,000 living, according to the World Wildlife Fund.

In addition, concerned parties have addressed the crisis on several science and ecological websites. Organizations such as the World Wide Fund for Nature, the African Wildlife Foundation, and others, are trying to focus attention on the extreme risk to the species. Some have suggested that a reserve be established in a more stable part of Africa, or on an island in a place such as Indonesia. Awareness is ever increasing, and even nonscientific or ecological sites have created various groups to collect donations to help with the conservation of this species.

Snow Leopard

The snow leopard or ounce (*Panthera uncia* syn. *Uncia uncia*) is a large cat native to the mountain ranges of Central and South Asia. It is listed as Endangered on the IUCN Red List of Threatened Species because as of 2003 the size of the global wild population was estimated at 4,080–6,590 adults. Fewer than 2,500 individuals may reproduce in the wild. As of 2016, estimates for the size of the global population vary from at least 4,080 to about 8,700 individuals.

Snow leopards inhabit alpine and subalpine zones at elevations from 3,000 to 4,500 m (9,800 to 14,800 ft). In the northern range countries, they also occur at lower elevations.

Taxonomically, the snow leopard was classified as *Uncia uncia* since the early 1930s. Based on genotyping studies, the cat has been considered a member of the genus *Panthera* since 2008. Two subspecies have been attributed, but genetic differences between the two have not been settled.

Naming and Etymology

Both the latinized genus name, *Uncia*, and the occasional English name *ounce* are derived from the Old French *once*, originally used for the European lynx. *Once* itself is believed to have arisen by back-formation from an earlier variant of *lynx*, *lonce* – the «l» of *lonce* was construed as an abbreviated *la* ('the'), leaving *once* to be perceived as the animal's name. This, like the English version *ounce*, came to be used for other lynx-sized cats, and eventually for the snow leopard.

The snow leopard is also known in its native lands as "*wāwrīn pṛāng*", "shan" (Ladakhi), "zigsa" (Tibetan), "irves" (Mongolian), "bars" or "barys" (Kazakh: , "ilbirs" (Kyrgyz), "barfānī chītā" and "him tendua".

According to the *American Heritage Dictionary*, the origin of the word *panthera* is unknown. A folk etymology derives the word from the Greek *pan* ("all") and *thēr* (beast of prey) because they can hunt and kill almost anything. It was proposed to have come ultimately into Greek from a Sanskrit word meaning "the yellowish animal" or "whitish-yellow". The Greek word *pánthēr*, referred to all spotted felines generically.

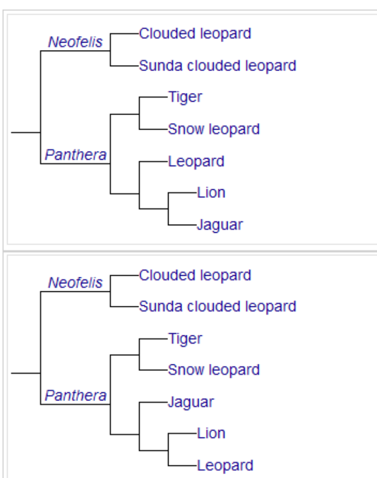
Taxonomy and Evolution

The species was first described by German naturalist Johann Christian Daniel von Schreber on the basis of an illustration in his 1777 publication *Die Säugethiere in Abbildungen nach der Natur mit Beschreibungen*. Schreber named the cat *Felis uncia* and gave its type locality as Barbary, Persia, East India, and China. In 1854, British zoologist John Edward Gray proposed the genus *Uncia*, to which he subordinated the snow leopard under the name *Uncia irbis*. British zoologist Reginald Innes Pocock corroborated this classification, but attributed the scientific name *Uncia uncia*. He also described morphological differences between snow leopards and the then-accepted members of *Panthera*.

The snow leopard is part of the *Panthera* lineage, one of the eight lineages of Felidae. This lineage comprises the species of *Panthera* and *Neofelis*. The Neofelis lineage diverged first from the within the Felinae. Subsequent branching between snow leopard and clouded leopard began two to three million years ago, but the details of this are disputed.

A 2006 phylogenetic study by Warren E. Johnson (of the National Cancer Institute) and colleagues, based on nDNA and mtDNA analysis, showed that the leopard is sister to two clades within *Panthera* - one consisting of the tiger and the snow leopard, and the other of the lion and the jaguar. This was seconded by a 2009 study by Lars Werdelin and colleagues. However, the results obtained in a 2010 study by Brian W. Davis (of the Texas A&M University) and colleagues and a 2011 study by Ji H. Mazák (of the Shanghai Science and Technology Museum) and colleagues showed a swapping between the leopard and the jaguar in the cladogram. A 2016 study indicates that at some point in their evolution, snow leopards interbred with lions, as their mitochondrial genomes are more similar to each other than their nuclear genomes. From this research, it is indicated that a female hybrid offspring of male ancestors of modern snow leopards and female ancestors of modern lions interbred with the male ancestors of modern snow leopards.

Closeup of a male snow leopard.



Two cladograms proposed for *Panthera*. The upper cladogram is based on the 2006 and 2009 studies, while the other is based on the 2010 and 2011 studies.

Subspecies

The snow leopard subspecies *U. u. baikalensis-romanii* was proposed for a population living in the southern Transbaikal region, which requires further evaluation. Authors of the Handbook of the Mammals of the World recognize two subspecies, namely *U. u. uncia* occurring in Mongolia and Russia; and *U. u. uncioides* living in western China and the Himalayas.

Description

Snow leopards are slightly smaller than the other big cats but, like them, exhibit a range of sizes, generally weighing between 27 and 55 kg (60 and 121 lb), with an occasional large male reaching 75 kg (165 lb) and small female of under 25 kg (55 lb). They have a relatively short body, measuring in length from the head to the base of the tail 75 to 150 cm (30 to 60 in). However, the tail is quite long, at 80 to 100 cm (31 to 39 in), with only the domestic-cat-sized marbled cat being relatively longer-tailed. They are stocky and short-legged big cats, standing about 60 cm (24 in) at the shoulder.

Snow leopard skull.

Snow leopards have long, thick fur, and their base color varies from smoky gray to yellowish tan, with whitish underparts. They have dark grey to black open rosettes on their bodies, with small spots of the same color on their heads and larger spots on their legs and tails. Unusually among cats, their eyes are pale green or grey in color.

Snow leopards show several adaptations for living in a cold, mountainous environment. Their bodies are stocky, their fur is thick, and their ears are small and rounded, all of which help to minimize heat loss. Their paws are wide, which distributes their weight better for walking on snow, and have fur on their undersides to increase their grip on steep and unstable surfaces; it also helps to minimize heat loss. Snow leopards' tails are long and flexible, helping them to maintain their balance, which is very important in the rocky terrain they inhabit. Their tails are also very thick due to storage of fat and are very thickly covered with fur which allows them to be used like a blanket to protect their faces when asleep.

The snow leopard has a short muzzle and domed forehead, containing unusually large nasal cavities that help the animal breathe the thin, cold air of their mountainous environment.

The snow leopard cannot roar, despite possessing partial ossification of the hyoid bone. This partial ossification was previously thought to be essential for allowing the big cats to roar, but new studies show the ability to roar is due to other morphological features, especially of the larynx, which are absent in the snow leopard. Snow leopard vocalizations include hisses, chuffing, mews, growls, and wailing.

Snow leopards were only reclassified as a member of the Panthera genus (big cats) following a genetic study by Mr Brian Davis, Dr Gang Li and Professor William Murphy in 2009. This study showed that snow leopards actually evolved alongside tigers and not leopards as previously thought.

Distribution and Habitat

The snow leopard is distributed from the west of Lake Baikal through southern Siberia, in the Kunlun Mountains, in the Russian Altai mountains, Sayan and Tannu-Ola Mountains, in the Tian Shan, across Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan to the Hindu Kush in eastern Afghanistan, Karakoram in northern Pakistan, in the Pamir Mountains, and in the high altitudes of the Himalayas in India, Nepal, and Bhutan, and the Tibetan Plateau. In Mongolia, it is found in the Mongolian and Gobi Altai Mountains and the Khangai Mountains. In Tibet, it is found up to the Altyn-Tagh in the north.

Snow leopard at Hemis National Park, India.

Potential snow leopard habitat in the Indian Himalayas is estimated at less than 90,000 km^2 (35,000 sq mi) in the states of Jammu and Kashmir, Uttarakhand, Himachal Pradesh, Sikkim, and Arunachal Pradesh, of which about 34,000 km^2 (13,000 sq mi) is considered good habitat, and 14.4% is protected. In the beginning of the 1990s, the Indian snow leopard population was estimated at roughly 200–600 individuals living across about 25 protected areas.

In summer, snow leopards usually live above the tree line on mountainous meadows and in rocky regions at altitudes from 2,700 to 6,000 m (8,900 to 19,700 ft). In winter, they come down into the forests to altitudes around 1,200 to 2,000 m (3,900 to 6,600 ft). Snow leopards prefer rocky, broken terrain, and can travel without difficulty in snow up to 85 cm (33 in) deep, although they prefer to use existing trails made by other animals.

Snow leopard in Ladakh

Global warming has caused the tree line to be increased in altitude, resulting in the decrease of wild prey that depend on the plants for food.

Ecology and Behavior

The snow leopard is solitary, except for females with cubs. They rear them in dens in the mountains for extended periods.

Snow leopard in Wakhan district, Afghanistan.

An individual snow leopard lives within a well-defined home range, but does not defend its territory aggressively when encroached upon by other snow leopards. Home ranges vary greatly in size. In Nepal, where prey is abundant, a home range may be as small as 12 km² (5 sq mi) to 40 km² (15 sq mi) and up to five to 10 animals are found here per 100 km² (39 sq mi); in habitats with sparse prey, though, an area of 1,000 km² (386 sq mi) supports only five of these cats. However, a new study lasting from 2008 to 2014 indicates their ranges are much greater than believed; a male snow leopard requires a territory of around 80 square miles, while females require up to 48 square miles of territory. Taking this data into account, it is estimated that 40 percent of the 170 protected areas in place are smaller than the space required to support a single male snow leopard.

Like other cats, snow leopards use scent marks to indicate their territories and common travel routes. These are most commonly produced by scraping the ground with the hind feet before depositing urine or scat, but they also spray urine onto sheltered patches of rock.

Snow leopards are crepuscular, being most active at dawn and dusk. They are known for being extremely secretive and well camouflaged.

Hunting and Diet

Snow leopard with Himalayan marmot, Kyrgyzstan

Snow leopards are carnivores and actively hunt their prey. Like many cats, they are also opportunistic feeders, eating whatever meat they can find, including carrion and domestic livestock. They can kill animals two to four times their own weight, such as the bharal, Himalayan tahr, markhor, argali, horse, and camel, but will readily take much smaller prey, such as hares and birds. They are capable of killing most animals in their range with the probable exception of the adult male yak. Unusually among cats, snow leopards also eat a significant amount of vegetation, including grass and twigs. Snow leopards will also hunt in pairs successfully, especially mating pairs.

A snow leopard eating at Ménagerie du Jardin des plantes, Paris.

The diet of the snow leopard varies across its range and with the time of year, and depends on prey availability. In the Himalayas, it preys mostly on bharals (Himalayan blue sheep), but in other mountain ranges, such as the Karakoram, Tian Shan, Altai and Tost Mountains of Mongolia, its main prey consists of Siberian ibex and argali, a type of wild sheep, although the latter has become rarer in some parts of the snow leopard's range. Other large animals eaten when available can include various types of wild goats and sheep (such as markhors and urials), other goat-like ruminants such as Himalayan tahr and gorals, plus deer, red panda, wild boars, and langur monkeys. Smaller prey consists of marmots, woolly hares, pikas, various rodents, and birds such as the snow cock and chukar.

Considerable predation of domestic livestock occurs, which brings it into direct conflict with humans. However, even in Mongolia, where wild prey have been reduced and interactions with humans are common, domestic livestock (mainly domestic sheep) comprise less than 20% of the diet of species, with wild prey being taken whenever possible. Herders will kill snow leopards to prevent them from taking their animals. The loss of prey animals due to overgrazing by domestic livestock, poaching, and defense of livestock are the major drivers for the decreasing population of the snow leopard. The snow leopard has not been reported to attack humans, and appears to be the least aggressive to humans of all big cats. As a result, they are easily driven away from livestock; they readily abandon their kills when threatened, and may not even defend themselves when attacked.

Snow leopards prefer to ambush prey from above, using broken terrain to conceal their approach. They will actively pursue prey down steep mountainsides, using the momentum of their initial leap to chase animals for up to 300 m (980 ft). They kill with a bite to the neck, and may drag the prey to a safe location before feeding. They consume all edible parts of the carcass, and can survive on a single bharal for two weeks before hunting again. Annual prey needs appears to be 20–30 adult blue sheep.

Reproduction and Life Cycle

Snow leopards are unusual among large cats in that they have a well-defined birth peak. They usually mate in late winter, marked by a noticeable increase in marking and calling. Snow leopards have a gestation period of 90–100 days, so the cubs are born between April and June. Oestrus typically lasts from five to eight days, and males tend not to seek out another partner after mating, probably because the short mating season does not allow sufficient time. Paired snow leopards mate in the usual felid posture, from 12 to 36 times a day.

Snow leopard cubs at the Cat Survival Trust, Welwyn, UK.

The oldest known snow leopard, Shynghyz at Tama Zoo, Tokyo

The mother gives birth in a rocky den or crevice lined with fur shed from her underside. Litter sizes vary from one to five cubs, but the average is 2.2. The cubs are blind and helpless at birth, although already with a thick coat of fur, and weigh from 320 to 567 g (11.3 to 20.0 oz). Their eyes open at around seven days, and the cubs can walk at five weeks and are fully weaned by 10 weeks. Also when they are born, they have full black spots which turn into rosettes as they grow to adolescence.

The cubs leave the den when they are around two to four months of age, but remain with their mother until they become independent after around 18–22 months. Once independent, they may disperse over considerable distances, even crossing wide expanses of flat terrain to seek out new hunting grounds. This likely helps reduce the inbreeding that would otherwise be common in their relatively isolated environments. Snow leopards become sexually mature at two to three years, and normally live for 15–18 years, although in captivity they can live for up to 25 years.

Conservation Efforts

Numerous agencies are working to conserve the snow leopard and its threatened mountain ecosystems. These include the Snow Leopard Trust, the Snow Leopard Conservancy, the Snow Leopard Network, the Cat Specialist Group, and the Panthera Corporation.

These groups and various national governments from the snow leopard's range, non-profits, and donors from around the world worked together at the 10th International Snow Leopard Conference in Beijing. Their focus on research, community programs in snow leopard regions, and education programs are aimed at understanding the cat's needs, as well as the needs of the villagers and herder communities juxtaposed with the snow leopards' habitats.

Global Snow Leopard Forum

In 2013 government leaders and officials from all 12 countries encompassing the snow leopard's range (Afghanistan, Bhutan, China, India, Kazakhstan, Kyrgyz Republic, Mongolia, Pakistan, Russia, Tajikistan, and Uzbekistan) came together at the Global Snow Leopard Forum (GSLF) initiated by the President Almazbek Atambayev of the Kyrgyz Republic, and the State Agency on Environmental Protection and Forestry under the government of the Kyrgyz Republic. The meeting was held in Bishkek, the capital of the Kyrgyz Republic, and all countries agreed that the snow leopard and the high mountain habitat it lives in need trans-boundary support to ensure a viable future for snow leopard populations, as well as to safeguard their fragile environment. The event brought together many partners, including NGOs like the Snow Leopard Conservancy, the Snow Leopard Trust, and the Nature and Biodiversity Conservation Union. Also supporting the initiative were the Snow Leopard Network, the World Bank's Global Tiger Initiative, the United Nations Development Programme, the World Wild Fund for Nature, the United States Agency for International Development, and Global Environment Facility.

Bishkek Declaration

At the GSLF meeting, the 12 range countries signed the Bishkek Declaration to "acknowledge that the snow leopard is an irreplaceable symbol of our nations' natural and cultural heritage and an indicator of the health and sustainability of mountain ecosystems; and we recognize that mountain ecosystems inhabited by snow leopards provide essential ecosystem services, including storing and releasing water from the origins of river systems benefitting one-third of the world's human population; sustaining the pastoral and agricultural livelihoods of local communities which depend on biodiversity for food, fuel, fodder, and medicine; and offering inspiration, recreation, and economic opportunities."

Global Snow Leopard and Eco-system Protection Program

Out of these efforts was formed a cooperative support effort, the Global Snow Leopard and Eco-system Protection Program (GSLEP). The GSLEP is a joint initiative of range country governments, international agencies, civil society, and the private sector. Its goal is to secure the long-term survival of the snow leopard in its natural ecosystem.

The goal of the GSLEP is for the 12 snow leopard range countries, with support from conservation agencies, NGO's and others to work together to identify and secure at least 20 healthy populations of snow leopards across the cat's range by 2020, or "20 by 2020". Many of these populations will cross international boundaries.

The three criteria that will secure healthy populations of snow leopards are populations which represent at least 100 breeding age snow leopards, contain adequate and secure prey populations and have connectivity to other snow leopard populations.

This is an interim goal for the years through to 2020. During the coming years, agreement will be reached on the steps needed to achieve the ultimate goal of ensuring that healthy snow leopard populations remain the icon of the mountains of Asia for generations to come.

2015 Designated International Year of the Snow Leopard

To help spread the word amongst the people, government authorities, and conservation groups in each range country, 2015 was designated the International Year of the Snow Leopard as part of the GSLEPP's work. All range-country governments, nongovernmental and inter-governmental organizations, local communities, and various private sector businesses pledged to take the year as an opportunity to further work towards conservation of snow leopards and their high-mountain ecosystems.

Population and Protected Areas

The total wild population of the snow leopard was estimated at 4,510 to 7,350 individuals. Many of these estimates are rough and outdated. An estimate from 2016, using data from a number of studies, proposed a population of 4,700 to 8,700 individuals across only 32 percent of the species' range, suggesting that the total number of snow leopards was larger than previously thought. This estimate has been disputed by other conservationists, including Gustaf Samelius and Som Ale, who have raised concerns about the scientific validity of the data used in that estimate.

Snow leopard at zoo d'Amnéville, France, showing the thickly furred tail

Snow leopard

In 1972, the International Union for Conservation of Nature (IUCN) placed the snow leopard on its Red List of Threatened Species as endangered; the same threat category was applied in the assessment conducted in 2008.

There are also approximately 600 snow leopards in zoos around the world. The Richmond Metropolitan Zoo in Virginia, in the United States of America, has newly-born snow leopard cubs.

Range Country	Habitat Area (km^2)	Estimated Population
Afghanistan	50,000	100–200?
Bhutan	15,000	100–200?
China	1,100,000	2,000–2,500
India	75,000	200–600
Kazakhstan	50,000	180–200
Kyrgyzstan	105,000	150–500
Mongolia	101,000	500–1,000
Nepal	30,000	300–500
Pakistan	80,000	200–420
Tajikistan	100,000	180–220
Uzbekistan	10,000	20–50

Snow leopard

Protected areas:

- Chitral National Park, in the Khyber-Pakhtunkhwa, Pakistan
- Hemis National Park, in Ladakh, Jammu and Kashmir, India
- Khunjerab National Park, Gilgit-Baltistan, Pakistan
- Nanda Devi National Park, in state of Uttarakhand, India, a UNESCO Natural World Heritage Site
- Qomolangma National Nature Preserve, Tibet, China
- Sagarmatha National Park, Nepal, a UNESCO Natural World Heritage Site.

- Tumor Feng Nature Reserve, western Tianshan Mountains, Xinjiang, China.
- Valley of Flowers National Park, Uttarakhand, India, a UNESCO Natural World Heritage Site
- Shey-Phoksundo National Park, Dolpa, Nepal
- Dhorpatan Hunting Reserve, Baglung, Nepal
- Annapurna Conservation Area, Western Nepal
- Api Nampa Conservation Area, Western Nepal
- Jigme Dorji National Park, Bhutan
- Gobi Gurvansaikhan National Park, Mongolia
- Ubsunur Hollow, on the territorial border of Mongolia and the Republic of Tuva, Russia
- Dibang Wildlife Sanctuary, near Anini, India
- Aksu-Djabagly Nature Reserve, Kazakhstan
- Sarychat-Ertash State Nature Reserve, Kyrgyzstan
- Katun Nature Reserve, Russia
- Kibber Wildlife Sanctuary, Lahaul Spiti, Himachal Pradesh, India
- Pin Valley National Park, Lahaul Spiti, Himachal Pradesh, India
- Great Himalayan National Park, Kullu, Himachal Pradesh, India
- Sacred Himalayan Landscape, Nepal, India, Bhutan

Much progress has been made in securing the survival of the snow leopard, with them being successfully bred in captivity. The animals usually give birth to two to three cubs in a litter, but can give birth to up to seven in some cases.

A "surprisingly healthy" population of snow leopards has been found living at 16 locations in the isolated Wakhan Corridor in northeastern Afghanistan, giving rise to hopes for survival of snow leopards in that region.

Relationships with Humans

Attacks on Humans and Livestock

Snow leopard attacks on humans are rare; only two instances are known. On July 12, 1940, in Maloalmaatinsk gorge near Almaty, a rabid snow leopard attacked two men during the day and inflicted serious injuries on both. In the second case, not far from Almaty, an old, toothless, emaciated snow leopard unsuccessfully attacked a passerby in winter; it was captured and carried to a local village. There are no other records of any snow leopard attacking a human being.

A 2008 *Natural World* episode, “Snow Leopard – Beyond the Myth”, interviewed a couple with a goat farm in Pakistan; the woman was bowled over by snow leopard escaping an enclosure where it had been feeding on the livestock, but she was not attacked by the cat, despite fainting and being helpless. The film crew went to some lengths to demonstrate that the cat was primarily hunting wild prey and was often ranging far outside the area, as they hoped to prevent local farmers from shooting it. Nevertheless, they also found evidence of other sightings of the cats around nearby human settlements, and of repeated attacks on livestock (some of them unsuccessful). Predation of livestock by snow leopards has also been a subject of conservation journal papers.

Emblematic Use

Snow leopards have symbolic meaning for Turkic peoples of Central Asia, where the animal is known as *irbis* or *bars*, so it is widely used in heraldry and as an emblem.

Ounce

The snow leopard in heraldry is sometimes known in English as the *ounce*. The cat has long been used as a political symbol, the *Aq Bars* (‘White Leopard’), by Tatars, Kazakhs, and Bulgars, among others. A snow leopard is found on the official seal of the city of Almaty, Kazakhstan, and the former 10,000 Kazakhstani tenge banknote also featured one on the reverse. A mythical winged *Aq Bars* is found in the national coat of arms of Tatarstan, the seal of the city of Samarqand, Uzbekistan, and (also with a crown) the old coat of arms of the Kazakh capital, Astana. In Kyrgyzstan, it has been used in highly stylized form in the modern emblem of the capital, Bishkek, and the same art has been integrated into the badge of the Kyrgyzstan Girl Scouts Association. A crowned snow leopard features in the arms of Shushensky District, Krasnoyarsk Krai, Russia. The animal has also featured in the coat of arms of Ossetia since 1735, and has been adopted into those of modern-day North Ossetia-Alania and two entities claiming to be the legitimate government of South Ossetia.

The Snow Leopard award, given to Soviet mountaineers who scaled all five of the Soviet Union’s 7,000-meter peaks, is named after the animal, but does not depict one.

The cat is the state animal of Himachal Pradesh, a north Indian state in the western Himalayas. The animal has also been declared the "National Predator" of Pakistan.

Symbol of Almaty, Kazakhstan

Snow leopard on the reverse of the old 10,000-Kazakhstani tenge banknote

The coat of arms of Tatarstan

In the Media

Documentary

Documentary footage of the snow leopard is scarce. While such coverage would not be remarkable with regard to common species, wildlife video of the snow leopard is difficult to obtain due to the animal's rarity and the human inaccessibility of much of its natural habitat.

The BBC One TV series *Planet Earth* had a segment on snow leopards. The series took some of the first video of snow leopards in the wild, and also featured a snow leopard hunting a markhor.

Nisar Malik, a Pakistani journalist, and Mark Smith, a cameraman who had worked on the *Planet Earth* segment, spent a further 18 months filming snow leopards in the Hindu Kush for the BBC Two series *Natural World* episode "Snow Leopard – Beyond the Myth". The cat has been featured in segments of other episodes of the same series.

The PBS/WNET series *Nature* focused on the species in its episode "Silent Roar: Searching for the Snow Leopard".

Non-Fiction

In Peter Matthiessen's 1978 travelogue *The Snow Leopard*, he recounts his two-month search with naturalist George Schaller for snow leopards in Nepal.

Fictional

In Philip Pullman's 1995-2000 fantasy trilogy *His Dark Materials*, Lord Asriel's dæmon is a snow leopard named Stelmaria.

Tai Lung, the main antagonist of the 2008 film *Kung Fu Panda*, is an anthropomorphized snow leopard.

In the 2013 film *The Secret Life of Walter Mitty*, photojournalist Sean O'Connell (played by Sean Penn) is shown photographing snow leopards in Afghanistan.

Latent Extinction Risk

In conservation biology, latent extinction risk is a measure of the potential for a species to become threatened.

Latent risk can most easily be described as the difference, or discrepancy, between the current observed extinction risk of a species (typically as quantified by the [IUCN Red List]) and the theoretical extinction risk of a species predicted by its biological or life history characteristics.

Calculation

Because latent risk is the discrepancy between current and predicted risks, estimates of both of these values are required. Once these values are known, the latent extinction risk can be calculated as *Predicted Risk - Current Risk = Latent Extinction Risk*.

When the latent extinction risk is a positive value, it indicates that a species is currently less threatened than its biology would suggest it ought to be. For example, a species may have several of the characteristics often found in threatened species, such as large body size, small geographic distribution, or low reproductive rate, but still be rated as "least concern" in the IUCN Red List. This may be because it has not yet been exposed to serious threatening processes such as habitat degradation.

Conversely, negative values of latent risk indicate that a species is already more threatened than its biology would indicate, probably because it inhabits a part of the world where it has been exposed to extreme endangering processes. Species with severely low negative values are usually listed as an endangered species and have associated recovery and conservation plans.

Limits

One of the issues associated with latent extinction risk is its difficulty to calculate because of the limited availability of data for predicting extinction risk across large numbers of species. Hence, the only study of latent risk to date has focused on mammals, which are one of the best-studied groups of organisms.

Effects on Conservation

A study of latent extinction risk in mammals identified a number of "hotspots" where the average value of latent risk for mammal species was unusually high. This study suggested that these areas represented an opportunity for proactive conservation efforts, because these could become the "future battlegrounds of mammal conservation" if levels of human impact increase. Unexpectedly, the hotspots of mammal latent risk include large areas of Arctic America, where overall mammal diversity is not high, but where many species have the kind of biological traits (such as large body size and slow reproductive rate) that could render them extinction-prone. Another notable region of high latent risk for mammals is the island chain of Indonesia and Melanesia, where there are large numbers of restricted-range endemic species.

Because it is much more cost-effective to prevent species declines before they happen than to attempt to rescue species from the brink of extinction, latent risk hotspots could form part of a global scheme to prioritize areas for conservation effort, together with other kinds of priority areas such as biodiversity hotspots.

IUCN Red List

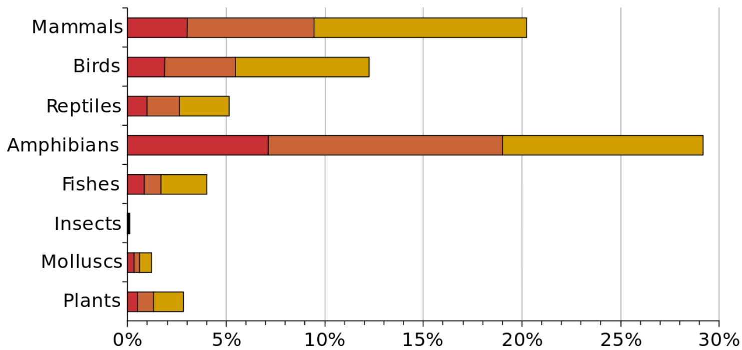
The IUCN Red List of Threatened Species (also known as the IUCN Red List or Red Data List), founded in 1964, is the world's most comprehensive inventory of the global conservation status of biological species. The International Union for Conservation of Nature (IUCN) is the world's main authority on the conservation status of species. A series of Regional Red Lists are produced by countries or organizations, which assess the risk of extinction to species within a political management unit.

The IUCN Red List is set upon precise criteria to evaluate the extinction risk of thousands of species and subspecies. These criteria are relevant to all species and all regions of the world. The aim is to convey the urgency of conservation issues to the public and policy makers, as well as help the international community to try to reduce species extinction. According to IUCN (1996), the formally stated goals of the Red List are (1) to provide scientifically based information on the status of species and subspecies at a global level, (2) to draw attention to the magnitude and importance of threatened biodiversity, (3) to influence national and international policy and decision-making, and (4) to provide information to guide actions to conserve biological diversity.

Major species assessors include BirdLife International, the Institute of Zoology (the research division of the Zoological Society of London), the World Conservation Monitoring Centre, and many Specialist Groups within the IUCN Species Survival Commission (SSC). Collectively, assessments by these organizations and groups account for nearly half the species on the Red List.

The IUCN aims to have the category of every species re-evaluated every five years if possible, or at least every ten years. This is done in a peer reviewed manner through IUCN Species Survival Commission (SSC) Specialist Groups, which are Red List Authorities responsible for a species, group of species or specific geographic area, or in the case of BirdLife International, an entire class (Aves).

History



The percentage of species in several groups which are listed as critically endangered, endangered, or vulnerable on the 2007 IUCN Red List.

1964 Red List of Threatened Plants

The 1964 IUCN Red List of Threatened Plants used the older pre-criteria Red List assessment system. Plants listed may not, therefore, appear in the current Red List. IUCN advise that is best to check both the online Red List and the 1997 plants Red List publication.

2006 Release

The 2006 Red List, released on 4 May 2006 evaluated 40,168 species as a whole, plus an additional 2,160 subspecies, varieties, aquatic stocks, and subpopulations.

2007 Release

On 12 September 2007, the World Conservation Union (IUCN) released the 2007 IUCN Red List of Threatened Species. In this release, they have raised their classification of both the western lowland gorilla (*Gorilla gorilla gorilla*) and the Cross River gorilla (*Gorilla gorilla diehli*) from endangered to critically endangered, which is the last category before extinct in the wild, due to Ebola virus and poaching, along with other factors. Russ Mittermeier, chief of Swiss-based IUCN's Primate Specialist Group, stated that 16,306 species are endangered with extinction, 188 more than in 2006 (total of 41,415 species on the Red List). The Red List includes the Sumatran orangutan (*Pongo abelii*) in the Critically Endangered category and the Bornean orangutan (*Pongo pygmaeus*) in the Endangered category.

2008 Release

The 2008 Red List was released on 6 October 2008, at the IUCN World Conservation Congress in Barcelona, and "has confirmed an extinction crisis, with almost one in four [mammals] at risk of disappearing forever". The study shows at least 1,141 of the 5,487 mammals on Earth are known to be threatened with extinction, and 836 are listed as Data Deficient.

2012 Release

The Red List of 2012 was released 19 July 2012 at Rio+20 Earth Summit; nearly 2,000 species were added, with 4 species to the extinct list, 2 to the rediscovered list. The IUCN assessed a total of 63,837 species which revealed 19,817 are threatened with extinction. With 3,947 described as "critically endangered" and 5,766 as "endangered", while more than 10,000 species are listed as "vulnerable". At threat are 41% of amphibian species, 33% of reef-building corals, 30% of conifers, 25% of mammals, and 13% of birds. The IUCN Red List has listed 132 species of plants and animals from India as "Critically Endangered".

IUCN Red List Categories

Species are classified by the IUCN Red List into nine groups, set through criteria such as rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation.

- Extinct (EX) – No known individuals remaining.
- Extinct in the wild (EW) – Known only to survive in captivity, or as a naturalized population outside its historic range.
- Critically endangered (CR) – Extremely high risk of extinction in the wild.
- Endangered (EN) – High risk of extinction in the wild.
- Vulnerable (VU) – High risk of endangerment in the wild.
- Near threatened (NT) – Likely to become endangered in the near future.
- Least concern (LC) – Lowest risk. Does not qualify for a more at-risk category. Widespread and abundant taxa are included in this category.

- Data deficient (DD) – Not enough data to make an assessment of its risk of extinction.
- Not evaluated (NE) – Has not yet been evaluated against the criteria.

When discussing the IUCN Red List, the official term "threatened" is a grouping of three categories: Critically Endangered, Endangered, and Vulnerable.

1994 Categories and Criteria

The older 1994 has only a single "Lower Risk" category which contained three subcategories:

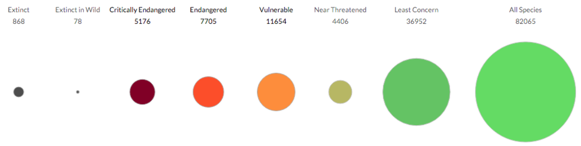
- Conservation Dependent (LR/cd)
- Near Threatened (LR/nt)
- Least Concern (LR/lc)

In the 2001 system Near Threatened and Least Concern have now become their own categories, while Conservation Dependent is no longer used and has been merged into Near Threatened.

Possibly Extinct

The tag of "possibly extinct" (PE) is used by Birdlife International, the Red List Authority for birds for the IUCN Red List. BirdLife International has recommended PE become an official tag for Critically Endangered species, and this has now been adopted, along with a "Possibly Extinct in the Wild" tag for species with populations surviving in captivity but likely to be extinct in the wild (e.g. Spix's macaw).

Versions



Comparing the number of species in each category of IUCN Red List.

There have been a number of versions, dating from 1991, including:

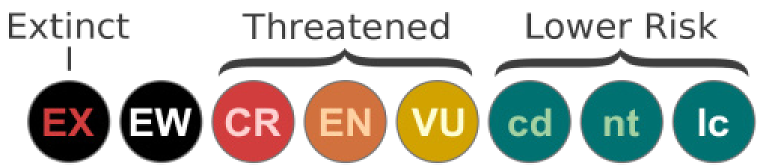
- Version 1.0 (1991)
- Version 2.0 (1992)
- Version 2.1 (1993)
- Version 2.2 (1994)

- Version 2.3 (1994)
- Version 3.0 (1999)
- Version 3.1 (2001)
- Version 4 (2015)

For plants, the 1997 Red List is the most important source.

Criticism

In 1997, the IUCN Red List came under criticism on the grounds of secrecy (or at least poor documentation) surrounding the sources of its data.



1994 IUCN Red List categories (version 2.3), used for species which have not been reassessed since 2001.

These allegations have led to efforts by the IUCN to improve its documentation and data quality, and to include peer reviews of taxa on the Red List. The list is also open to petitions against its classifications, on the basis of documentation or criteria. A *Nature* editorial defended the Red List's relevance in October 2008.

It has been suggested that the IUCN Red List and similar works are prone to misuse by governments and other groups that draw possibly inappropriate conclusions on the state of the environment or to effect exploitation of natural resources.

Minimum Viable Population

Minimum viable population (MVP) is a lower bound on the population of a species, such that it can survive in the wild. This term is used in the fields of biology, ecology, and conservation biology. More specifically, MVP is the smallest possible size at which a biological population can exist without facing extinction from natural disasters or demographic, environmental, or genetic stochasticity. The term "population" rarely refers to an entire species. For example, the undomesticated dromedary camel is extinct in its natural wild habitat; but there is a domestic population in captivity and an additional feral population in Australia. Two groups of house cats in separate houses which are not allowed outdoors are also technically distinct populations. Typically, however, MVP is used to refer solely to a wild population, such as the red wolf.

Estimation

Minimum viable population is usually estimated as the population size necessary to ensure between 90 and 95 percent probability of survival between 100 and 1,000 years into the future. The MVP can be estimated using computer simulations for population viability analyses (PVA). PVA models populations using demographic and environmental information to project future population dynamics. The probability assigned to a PVA is arrived at after repeating the environmental simulation thousands of times.

For example, for a theoretical simulation of a population of 50 giant pandas in which the simulated population goes completely extinct, 30 out of 100 stochastic simulations projected 100 years into the future are not viable. Causes of extinction in the simulation may include inbreeding depression, natural disaster, or climate change. Extinction occurring in 30 out of 100 runs would give a survival probability of 70%. In contrast, in the same simulation with a starting population of 60 pandas, the panda population may only become extinct in four of the hundred runs, resulting in a survival probability of 96%. In this case the minimum viable population that satisfies the 90- to 95% probability for survival is between 50 and 60 pandas. (These figures have been invented for the purpose of this example.)

MVP and Extinction

MVP does not take human intervention into account. Thus, it is useful for conservation managers and environmentalists; a population may be increased above the MVP using a captive breeding program, or by bringing other members of the species in from other reserves.

In 1912, the Laysan duck had an effective population size of 7 at most.

There is naturally some debate on the accuracy of PVAs, since a wide variety of assumptions generally are required for future forecasting; however, the important consideration is not absolute accuracy, but promulgation of the concept that each species indeed has an MVP, which at least can be approximated for the sake of conservation biology and Biodiversity Action Plans.

There is a marked trend for insularity, surviving genetic bottlenecks and r-strategy to allow far lower MVPs than average. Conversely, taxa easily affected by inbreeding depression – having high MVPs – are often decidedly K-strategists, with low population densities while occurring over a wide range. An MVP of 500 to 1,000 has often been given as an average for terrestrial vertebrates when inbreeding or genetic variability is ignored. When inbreeding effects are included, estimates of MVP for many species are in the thousands. Based on a meta-analysis of reported values in the literature for many species, Traill *et al*. reported a median MVP of 4,169 individuals.

Population Uncertainty

Population uncertainty may be divided into four sources:

- Demographic stochasticity
- Environmental stochasticity
- Natural catastrophes
- Genetic stochasticity

Effective Population Size

The effective population size is the number of individuals that an idealised population would need to have, in order for some specified quantity of interest to be the same in the idealised population as in the real population. Idealised populations are based on unrealistic but convenient simplifications such as random mating, simultaneous birth of each new generation, constant population size, and equal numbers of children per parent. While in some simple scenarios, the effective population size can be equal to the number of breeding individuals in the population, for most quantities of interest and most real populations, the census population size N of a real population is usually larger than the effective population size N_e. The same population may have multiple effective population sizes, for different properties of interest, including for different genetic loci.

The effective population size is most commonly measured with respect to the coalescence time. In an idealised diploid population with no selection at any locus, the expectation of the coalescence time in generations is equal to twice the census population size. The effective population size is measured as within-species genetic diversity divided by four times the mutation rate, because in such an idealised population, the heterozygosity is equal to . In a population with selection at many loci and abundant linkage disequilibrium, the coales $4N\mu$ cent effective population size may not reflect the census population size at all, or may reflect its logarithm.

The concept of effective population size was introduced in the field of population genetics in 1931 by the American geneticist Sewall Wright.

Overview: Types of Effective Population Size

Depending on the quantity of interest, effective population size can be defined in several ways. Ronald Fisher and Sewall Wright originally defined it as "the number of breeding individuals in an idealised population that would show the same amount of dispersion of allele frequencies under random genetic drift or the same amount of inbreeding as the population under consideration". More generally, an effective population size may be defined as the number of individuals in an idealised population that has a value of any given population genetic quantity that is equal to the value of that quantity in the population of interest. The two population genetic quantities identified by Wright were the one-generation increase in variance across replicate populations (variance effective population size) and the one-generation change in the inbreeding coefficient (inbreeding effective population size). These two are closely linked, and derived from F-statistics, but they are not identical.

Today, the effective population size is usually estimated empirically with respect to the sojourn or coalescence time, estimated as the within-species genetic diversity divided by the mutation rate, yielding a coalescent effective population size. Another important effective population size is the selection effective population size $1/s_{critical}$, where $s_{critical}$ is the critical value of the selection coefficient at which selection becomes more important than genetic drift.

Empirical Measurements

In Drosophila populations of census size 16, the variance effective population size has been measured as equal to 11.5. This measurement was achieved through studying changes in the frequency of a neutral allele from one generation to another in over 100 replicate populations.

For coalescent effective population sizes, a survey of publications on 102 mostly wildlife animal and plant species yielded 192 N_e/N ratios. Seven different estimation methods were used in the surveyed studies. Accordingly, the ratios ranged widely from 10^{-6} for Pacific oysters to 0.994 for humans, with an average of 0.34 across the examined species. A genealogical analysis of human hunter-gatherers (Eskimos) determined the effective-to-census population size ratio for haploid (mitochondrial DNA, Y chromosomal DNA), and diploid (autosomal DNA) loci separately: the ratio of the effective to the census population size was estimated as 0.6–0.7 for autosomal and X-chromosomal DNA, 0.7–0.9 for mitochondrial DNA and 0.5 for Y-chromosomal DNA.

Variance Effective Size

In the Wright-Fisher idealized population model, the conditional variance of the allele frequency p', given the allele frequency p in the previous generation, is

$$\operatorname{var}(p' \mid p) = \frac{p(1-p)}{2N}.$$

Let $\widehat{\operatorname{var}}(p' \mid p)$ denote the same, typically larger, variance in the actual population under consideration. The variance effective population size $N_e^{(v)}$ is defined as the ~~size of~~ an idealized population with the same variance. This is found by substituting $\operatorname{var}(p' \mid p)$ for $\operatorname{var}(p' \mid p)$ and solving for N which gives

$$N_e^{(v)} = \frac{p(1-p)}{2\widehat{\operatorname{var}}(p)}$$

Theoretical Examples

In the following examples, one or more of the assumptions of a strictly idealised population are relaxed, while other assumptions are retained. The variance effective population size of the more relaxed population model is then calculated with respect to the strict model.

Variations in Population Size

Population size varies over time. Suppose there are t non-overlapping generations, then effective population size is given by the harmonic mean of the population sizes:

$$\frac{1}{N_e} = \frac{1}{t}\sum_{i=1}^{t}\frac{1}{N_i}$$

For example, say the population size was N = 10, 100, 50, 80, 20, 500 for six generations (t = 6). Then the effective population size is the harmonic mean of these, giving:

$$\frac{1}{N_e} = \frac{\frac{1}{10}+\frac{1}{100}+\frac{1}{50}+\frac{1}{80}+\frac{1}{20}+\frac{1}{500}}{6} = \frac{0.1945}{6} = 0.032416667$$

$$N_e = 30.8$$

Note this is less than the arithmetic mean of the population size, which in this example is 126.7. The harmonic mean tends to be dominated by the smallest bottleneck that the population goes through.

Dioeciousness

If a population is dioecious, i.e. there is no self-fertilisation then

$$N_e = N + \frac{1}{2}$$

or more generally,

$$N_e = N + \frac{D}{2}$$

where D represents dioeciousness and may take the value 0 (for not dioecious) or 1 for dioecious.

When N is large, N_e approximately equals N, so this is usually trivial and often ignored:

$$N_e = N + \frac{1}{2} \approx N$$

Variance in Reproductive Success

If population size is to remain constant, each individual must contribute on average two gametes to the next generation. An idealized population assumes that this follows a Poisson distribution so that the variance of the number of gametes contributed, k is equal to the mean number contributed, i.e. 2:

$$\mathrm{var}(k) = \bar{k} = 2.$$

However, in natural populations the variance is often larger than this. The vast majority of individuals may have no offspring, and the next generation stems only from a small number of individuals, so

$$\mathrm{var}(k) > 2.$$

The effective population size is then smaller, and given by:

$$N_e^{(v)} = \frac{4N - 2D}{2 + \mathrm{var}(k)}$$

Note that if the variance of k is less than 2, N_e is greater than N. In the extreme case of a population experiencing no variation in family size, in a laboratory population in which the number of offspring is artificially controlled, $V_k = 0$ and $N_e = 2N$.

Non-Fisherian Sex-ratios

When the sex ratio of a population varies from the Fisherian 1:1 ratio, effective population size is given by:

$$N_e^{(v)} = N_e^{(F)} = \frac{4N_m N_f}{N_m + N_f}$$

Where N_m is the number of males and N_f the number of females. For example, with 80 males and 20 females (an absolute population size of 100):

$$N_e = \frac{4 \times 80 \times 20}{80 + 20} = \frac{6400}{100} = 64$$

Again, this results in N_e being less than N.

Inbreeding Effective Size

Alternatively, the effective population size may be defined by noting how the average inbreeding coefficient changes from one generation to the next, and then defining N_e as the size of the idealized population that has the same change in average inbreeding coefficient as the population under consideration. The presentation follows Kempthorne (1957).

For the idealized population, the inbreeding coefficients follow the recurrence equation

$$F_t = \frac{1}{N}\left(\frac{1+F_{t-2}}{2}\right) + \left(1 - \frac{1}{N}\right)F_{t-1}.$$

Using Panmictic Index (1 – F) instead of inbreeding coefficient, we get the approximate recurrence equation

$$1 - F_t = P_t = P_0\left(1 - \frac{1}{2N}\right)^t.$$

The difference per generation is

$$\frac{P_{t+1}}{P_t} = 1 - \frac{1}{2N}.$$

The inbreeding effective size can be found by solving

$$\frac{P_{t+1}}{P_t} = 1 - \frac{1}{2N_e^{(F)}}.$$

This is

$$N_e^{(F)} = \frac{1}{2\left(1 - \frac{P_{t+1}}{P_t}\right)}$$

although researchers rarely use this equation directly.

Theoretical Example: Overlapping Generations and Age-Structured Populations

When organisms live longer than one breeding season, effective population sizes have to take into account the life tables for the species.

Haploid

Assume a haploid population with discrete age structure. An example might be an organism that can survive several discrete breeding seasons. Further, define the following age structure characteristics:

$v_i =$ Fisher's reproductive value for age i,

$\ell_i =$ The chance an individual will survive to age i, and

$N_0 =$ The number of newborn individuals per breeding season.

The generation time is calculated as

$$T = \sum_{i=0}^{\infty} \ell_i v_i = \text{average age of a reproducing individual}$$

Then, the inbreeding effective population size is

$$N_e^{(F)} = \frac{N_0 T}{1 + \sum_i \ell_{i+1}^2 v_{i+1}^2 \left(\frac{1}{\ell_{i+1}} - \frac{1}{\ell_i}\right)}.$$

Diploid

Similarly, the inbreeding effective number can be calculated for a diploid population with discrete age structure. This was first given by Johnson, but the notation more closely resembles Emigh and Pollak.

Assume the same basic parameters for the life table as given for the haploid case, but distinguishing between male and female, such as $N_0^{\,f}$ and $N_0^{\,m}$ for the number of newborn females and males, respectively (notice lower case f for females, compared to upper case F for inbreeding).

Coalescent Effective Size

According to the neutral theory of molecular evolution, a neutral allele remains in a population for Ne generations, where Ne is the effective population size. An idealised diploid population will have a pairwise nucleotide diversity equal to 4Ne, where is the mutation rate. The sojourn effective population size can therefore be estimated empirically by dividing the nucleotide diversity by the mutation rate.

The coalescent effective size may have little relationship to the number of individuals physically present in a population. Measured coalescent effective population sizes vary between genes in the same population, being low in genome areas of low recombination and high in genome areas of high recombination. Sojourn times are proportional to N in neutral theory, but for alleles under selection, sojourn times are proportional to log(N). Genetic hitchhiking can cause neutral mutations to have sojourn times proportional to log(N): this may explain the relationship between measured effective population size and the local recombination rate.

Selection effective size

In an idealised Wright-Fisher model, the fate of an allele, beginning at an intermediate frequency, is largely determined by selection if the selection coefficient $s >> 1/N$, and largely determined by neutral genetic drift if $s << 1/N$. In real populations, the cutoff value of s may depend instead on local recombination rates. This limit to selection in a real population may be captured in a toy Wright-Fisher simulation through the appropriate choice of Ne. Populations with different selection effective population sizes are predicted to evolve profoundly different genome architectures.

Nurgaliev's Law

In population dynamics, Nurgaliev's law is an equation that describes the rate of change of the size of a population at a given time, in terms of the current population size. It is a deterministic ordinary differential equation in which the rate of change is expressed as a quadratic function of the population size.

Specification

Nurgaliev's law is expressed as

$$\frac{dn}{dt} = an^2 - bn,$$

where 'n' is the size of a population, t is time measured in years, a is a half of the average probability of a birth of a male (the same for females) of a potential arbitrary parents pair within a year, b is an average probability of a death of a person within a year.

The first term is twice proportional to the half of population (number of males and number of females). The second term is responsible for death rate and has a clear and precise sense— death rates are constant in time but vary with position on the age scale (babies are at risk at birth, the middle aged are at risk of trauma, old men become ill). It is known to demographers, for example, that the probability of death within the first year of a life is precisely equal to similar probability for the 55th year of a life. Thus, in the given model, the average person dies under the same law as an unstable atomic nucleus decays.

Stability

The population has steady states at $n = 0, b/a$. The state with $n = 0$ is stable whereas the state with $n = b/a$ is unstable, meaning that the equation describes a population which crashes (tends to zero) when the death rate is greater than the birth rate and explodes (tends to infinity) when it is the birth rate that is greater.

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7

Comprehensive Study of Species Reintroduction

Humans have caused immense loss to the natural habitat of wild plants and animals. Species reintroduction is the release of animals and organisms from captivity into the wild. It is usually done for animals that are under threat and are very close to becoming extinct. Specific species reintroduction includes topics such as Siberian Tiger Re-population Project, Cheetah reintroduction in India and the Arabian Oryx reintroduction. The aspects elaborated in this section are of vital importance, and provide a better understanding of species reintroduction.

Species Reintroduction

Species reintroduction is the deliberate release of a species into the wild, from captivity or other areas where the animal survives. A species that needs reintroduction is usually one whose existence has become threatened or endangered in the wild. However, reintroduction of a species can also be for pest control. For example, wolves being reintroduced to a wild area because of an overpopulation of elk or deer. Because reintroduction may involve returning native species to localities where they had been extirpated, some prefer the term "reestablishment".

Reintroduction has been practiced for many years.

Principles of Reintroduction

Reintroduction and translocation are both important tools for population and species management. Translocation moves wild-caught animals from one natural location to another, while reintroduction moves captive-born animals into their natural historical range. "Much of the behavioral research required to obtain reproduction will also be critical for reintroduction, which depends on the development of behaviorally competent individuals. More behavioral research to select the best candidates and prepare them for the very different challenges that await them in nature will be essential also. Behaviorists will again play a crucial role in post-release monitoring to determine the behavioral deficiencies that limit the success of reintroductions. There may be no other conservation action where the skills of behavioral researchers are more essential than reintroduction." In situ conservation means "on site". In-situ conservation is the conservation of species diversity within normal and natural habitats and ecosystems. The challenge in using in-situ methods is to expand our vision of protected areas to include multiple use and extractive reserves to develop new models for conservation. In-Situ conservation uses innovative proposals such as damaged ecosystems to preserve rare, endangered, and threatened species and to expand the range of options available for economic development. Ex-situ conservation means literally, “off-site conservation”. It is the process of protecting an endangered species of plant or animal outside of its natural habitat. Capturing and relocating part of a population from a threatened habitat and placing it in a new location where it may have a better chance of survival is one example. Ex-situ conservation should only be used when In-Situ conservation cannot.

Education

Zoos are one of the most conventional methods of ex-situ conservation. Depending on their size and location, zoos receive between a few tens of thousands to several million visitors annually. Zoos provide education to the public about the many endangered species and explain the factors contributing the threats they face in their native habitats. Through ex-situ conservation methods they provide protected specimens for breeding and reintroduction into the wild. It has been suggested that this method should be used only when necessary and when In-Situ conservation is not possible.

Successes and Failures

Reintroduction biology is new and continues to be a work in progress. The IUCN/SSC Re-introduction Specialist Group & Environment Agency, in their 2011 Global Re-introduction Perspectives, compiled reintroduction case studies from around the world. 184 case studies were reported on a range of species which included invertebrates, fish, amphibians, reptiles, birds, mammals, and plants. Assessments from all of the studies included goals, success indicators, project summary, major difficulties faced, major lessons learned, and success of project with reasons for success or failure. The Siberian tiger population has rebounded from 40 individuals in the 1940s to around 500 in 2007. The Siberian tiger population is now the largest un-fragmented tiger population in the world. Yet, a high proportion of translocations and reintroductions have not been successful in establishing viable populations Black footed ferrets in North America have also been a highly successful reintroduced species. Husbandry techniques were refined and the first successful captive breeding occurred in 1987. For this species, disease management in captivity is paramount and strict protocols are followed. Genetic management is closely monitored and ferrets are bred using a mean-kinship strategy which provides genetic diversity when bred in captivity. To prepare them for reintroduction into their new “wild” habitat, captive-born ferrets are placed in outdoor pens, simulating quasi-natural conditions with dirt burrows and live prey. Ferrets that receive pre-release conditioning in outdoor pens prior to release have demonstrated 10-

fold higher survival rates in the wild than ferrets that receive no pre-release exposure. Ferrets are typically released in the fall during their natural dispersal and kits (young of the year) are the primary candidates.

Many factors can attribute to the success or failure of a reintroduction. Predators, food, pathogens, competitors, and weather can all affect a reintroduced population's ability to grow, survive, and reproduce. Animals raised in captivity may experience stress during captivity or translocation, which can weaken their immune systems. The IUCN reintroduction guidelines emphasize the need for an assessment of the availability of suitable habitat as a key component of reintroduction planning. Poor assessment of the release site can increase the chances that the species will reject the site and perhaps move to a less suitable environment. This can decrease the species fitness and thus decrease chances for survival. They state that restoration of the original habitat and amelioration of causes of extinction must be explored and considered as essential conditions for these projects. Unfortunately, the monitoring period that should follow re introductions often remains neglected.

Improving Research Techniques

A cooperative approach to reintroduction by ecologists and biologists could improve research techniques. For both preparation and monitoring of reintroductions, increasing contacts between academic population biologists and wildlife managers is encouraged within the Survival Species Commission and the IUCN. The IUCN states that a re-introduction requires a multidisciplinary approach involving a team of persons drawn from a variety of backgrounds. A survey by Wolf et al. in 1998 indicated that 64% of reintroduction projects have used subjective opinion to assess habitat quality. This means that most reintroduction evaluation has been based on human anecdotal evidence and not enough has been based on statistical findings. Seddon et al. (2007) suggest that researchers contemplating future reintroductions should specify goals, overall ecological purpose, and inherent technical and biological limitations of a given reintroduction, and planning and evaluation processes should incorporate both experimental and modeling approaches.

Monitoring the health of individuals, as well as the survival, is important; both before and after the reintroduction. Intervention may be necessary if the situation proves unfavorable. Population dynamics models that integrate demographic parameters and behavioral data recorded in the field can lead to simulations and tests of a priori hypotheses. Using previous results to design further decisions and experiments is a central concept of adaptive management. In other words, learning by doing can help in future projects. Population ecologists should therefore collaborate with biologists, ecologists, and wildlife management to improve reintroduction programs.

Survival Skills

It may be very hard to reintroduce species into the wild, even if their natural habitats were restored. Survival techniques, which are normally passed from parents to offspring during parenting, are lost. The genetics of the species is saved, but the natural memetics of the species is not.

Beginning in the 1980s, biologists have learned that many mammals and birds need to learn a lot to survive in the wild. Thus, reintroduction programmes have to be planned carefully, ensuring that the animals have the necessary survival skills. Biologists must also study the animals after the reintroduction to learn whether the animals are surviving and breeding, what effects the reintroduction has on the ecosystem, and how to improve the process.

Still, a vast number of animals may need to be reintroduced into the wild to be sure that enough of them learn how to survive. For instance, in reintroducing houbara bustards into the wild in the United Arab Emirates, more than 5,000 birds per year are used.

Re-introduction Specialist Group (RSG)

The RSG is a network of specialists whose aim is to combat the ongoing and massive loss of biodiversity by using re-introductions as a responsible tool for the management and restoration of biodiversity. It does this by actively developing and promoting sound inter-disciplinary scientific information, policy, and practice to establish viable wild populations in their natural habitats. The role of the RSG is to promote the re-establishment of viable populations in the wild of animals and plants. The need for this role was felt due to the increased demand from re-introduction practitioners, the global conservation community and increase in re-introduction projects worldwide.

Increasing numbers of animal and plant species are becoming rare, or even extinct in the wild. In an attempt to re-establish populations, species can – in some instances – be re-introduced into an area, either through translocation from existing wild populations, or by re-introducing captive-bred animals or artificially propagated plants.

United Kingdom

Ongoing or Successful Programs

Reserva CIBE

- European bison to the UK – (ongoing)
- Black grouse to Derbyshire – (ongoing)
- Common crane to Somerset – (ongoing)
- Corncrake to Cambridgeshire – (ongoing)
- Glanville fritillary butterfly to Somerset – (successful)
- European beaver to Scotland, England, and Wales – (successful in Scotland and Northern England)
- Great bustard to Salisbury Plain – (ongoing)
- Heath fritillary butterfly to Essex – (successful)
- Ladybird spider to Arne RSPB reserve in Dorset, England – (ongoing).
- Large blue butterfly in the West and The South West – (successful and ongoing)
- Northern goshawk – the existing UK population is believed to be derived from a mixture of escaped falconers' birds and deliberate introductions – (successful)
- Osprey to Rutland Water – (successful)
- Red kite in the Chiltern Hills, Black Isle, Northamptonshire, Dumfries and Galloway, Yorkshire, Perth and Kinross and Gateshead – (successful)
- Red squirrel to Anglesey – (successful and ongoing)
- Reindeer to the Cairngorms in Scotland – (semi-domesticated; successful)
- Scots pine to southern England – (unplanned, successful)
- Silver-washed fritillary to Essex – (ongoing, locally successful)
- Wild boar to several places in Britain – (accidental, successful)
- White-tailed eagle to the Hebrides – (successful)
- White-tailed eagle to the east coast of Scotland – (ongoing)

Planned or Proposed Programs

- Brown bear in the Scottish Highlands – (proposed)
- Elk to Great Britain – (proposed)
- European lynx in Wales, England and Scotland (proposed)
- Golden eagle in United States and Wales
- Gray wolf in Scotland – (proposed)

- Arctic wolf in northern Scotland
- White stork – (proposed)
- White-tailed eagle to England and Wales (planned – on hold while a suitable site is found)
- Gray whale to Atlantic Ocean and Irish Sea (proposed – considered not feasible technologically and biologically. Two vagrant individuals sighted in the Mediterranean Sea in 2010 and off Namibia in 2013, the latter is the first confirmation of the species in the Southern Hemisphere.)

Other Countries

Planned or Proposed Programmes

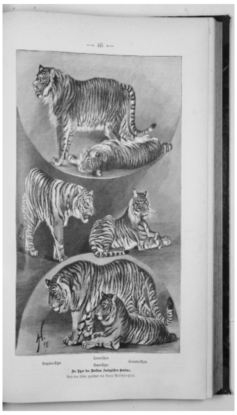
Lion reintroduction sites in India

- Asiatic Lion Reintroduction Project of Asiatic lion to Kuno Wildlife Sanctuary from their only home presently in the world at Gir Forest National Park. Kuno Wildlife Sanctuary is the chosen site for re-introducing and establishing the world's second completely separate population of the wild free ranging Asiatic lions in the state of Madhya Pradesh. It was decided to re-introduce the Asiatic lion in Kumbhalgarh Wildlife Sanctuary in Rajasthan. Some will be reintroduced in two locations in Gujarat.
- Siberian Tiger Re-population Project was proposed in 2009 to reintroduce Amur tigers back to their former lands and including the former ranges in Central Asia once inhabited by their closest relatives, the Caspian tigers. In 2010, two pairs of Siberian tigers, exchanged for Persian leopards to southwestern Russia, were set to be reintroduced in Iran's Miankaleh peninsula. Currently, the big cats (one of them had died) are being held in captivity in Eram zoo. Siberian tigers were also proposed to be reintroduced to a suitable habitat near the international river of Amu Darya in Central Asia and near the Ili River delta in Kazakhstan. A rewilding project at the Pleistocene Park, part of the re-population project was proposed back in 2005.

- Red deer - A programme was announced in 2013 to reintroduce the red deer to Armenia. 4 males and 11 females of the species will be purchased and transported to a breeding centre at Dilijan National Park. The World Wildlife Fund Germany and Orange Armenia have provided the funds for the project.
- Cheetah reintroduction in India is a project to reintroduce the cheetah in India. The Asiatic cheetah became extinct in 1947 when Maharaja of Surguja hunted the last three in the state of Rewa in central India. It was officially declared extinct in 1952 by the Indian government. Plans are going on to reintroduce the cheetah to two site in Madhya Pradesh (Kuno Wildlife Sanctuary and Nauradehi Wildlife Sanctuary) and in Rajasthan's Shahgarh Landscape. However, the Supreme court of India put a hold on this project as they recommended to protect the endangered lions first rather than import cheetah from Africa or Iran. (On hold)
- South China tiger - Captive tigers being re-wilded in Laohu Valley Reserve in the Free State province of South Africa under Save China's Tigers programme, will be eventually released back into the wilderness of China.

Siberian Tiger Re-population Project

The Siberian Tiger Re-population Project involves re-establishing populations of Amur tigers (*Panthera tigris altaica*) back to their former habitats, expanding their range, and also reintroducing the appropriate subspecies as replacements for the genetically similar Caspian tigers (*Panthera tigris virgata*) that previously existed in Central and West Asia. Currently, the Siberian tiger populations occur in cold regions of Russian Far East and northern China.



Caspian tiger (up), Bengal tiger (left), Sumatran tiger (right), Siberian tiger (down).

History

Siberian and Caspian tigers were revealed to be genetically close and shared the same ancestor that colonized Central Asia. They separated from each other for less than 10,000 years ago.

Two Siberian tigers at Harbin Siberian Tiger Park, Northeast China.

Siberian tigers used to be common in Northeast Asia from the Russian Far East, China, northeastern Mongolia to South Korea and near the Amur river whilst the Caspian tigers lived near the Caspian sea, mainly in Persia (today's Iran) in the Middle East, which included Turkmenistan to Kazakhstan and western Mongolia in northern Central Asia to Turkey and Armenia. Caspian tigers reportedly became extinct in the 1970s after several years of hunting, poaching and habitat loss. The Siberian tigers lost most of their ranges in Siberia and China and became extinct in the wild of Korea and Mongolia.

Siberian Tiger Project

A conservation project entitled *Siberian Tiger Project* was founded back in 1992.

A Siberian tiger at Minnesota Zoo.

The goal of the Siberian Tiger Project is to collect the best possible scientific information on tiger ecology for use in conservation plans. Through radio-tracking of more than 60 tigers since 1992, WCS specialists have studied their social structure, land use patterns, food habits, reproduction, mortality, and relationship with other species, including humans.

The Wildlife Conservation Society (WCS) has been active in the Russian Far East since 1992, working to conserve landscape species including Amur tigers, Far Eastern leopards and Blakiston's fish owls, whose survival ultimately requires the conservation of the forest ecosystem as a whole.

As a result, the WCS have consistently made sound conservation recommendations based upon comprehensive knowledge of tiger ecology and the role of tigers in the forested ecosystems of the Russian Far East. The Siberian Tiger Project positions WCS as scientific leaders in Russia, and gives the credibility to engage policy-makers as scientists with a real understanding of tiger conservation needs.

The Siberian Tiger Project has always sought to combine traditional Russian approaches to field research, such as snow track counts, and best approaches from abroad, such as radiotelemetry, in order to achieve new, ground-breaking results. Current research is focusing on cub mortality, dispersal and survivorship, comparison of density estimation techniques, and understanding the relationship between poaching and population structure and dynamics.

More than 500 Siberian tigers are left in the wild, with 95% of them in the Russian Far East and some remain in China. Within the tiger's range in Siberia, the largest protected area is the Sikhote-Alin Nature Reserve, a 401,428 ha (4000 km2) biosphere reserve at Primorsky Krai that has been a stronghold for the Amur tiger since its creation in 1935. In 1992 WCS (initially as the Hornocker Wildlife Institute) in cooperation with the Sikhote-Alin Nature Reserve began intensive studies of tiger ecology under the Siberian Tiger Project, today the world's longest running radio-telemetry based tiger research and conservation effort.

Reintroduction Efforts

A reintroduction project for tigers was proposed for the Middle East, Central to North Asia, choosing the Amur tigers are appropriate subspecies for reintroduction.

A Siberian tiger.

Kazakhstan

Siberian tigers are set to be reintroduced to suitable habitats in Kazakhstan where Caspian tigers once lived. A national park tentatively known as Caspian Tiger National Park for reintroduced Amur tigers might be opened in 2019.

The Amu-Darya's delta was suggested as a potential site. A feasibility study was initiated to investigate if the area is suitable and if such an initiative would receive support from relevant decision makers. A viable tiger population of about 100 animals would require at least 5,000 km^2 (1,900 sq mi) of large tracts of contiguous habitat with rich prey populations. Such habitat is not available at this stage and cannot be provided in the short term. The proposed region is therefore unsuitable for the reintroduction, at least at this stage.

Potential sites at southeastern Kazakhstan's river deltas such as Lake Balkhash and Ili River were also chosen as suitable habitats for the Siberian tigers. Dr. Igor Chestin of World Wide Fund for Nature (WWF) hopes to reintroduce tigers into the wild in Kazakhstan's marshy Balkhash region within the next few years, though there are needs to reestablish the potential prey base in the areas first, such as saiga antelopes and goitered gazelles. A reintroduction of the Bactrian deer to the Ili delta and the Asiatic wild ass to the Kazakh steppes are under work.

Iran

Caspian tigers used to live in northwestern to northeastern Iran. In 2010, two Siberian tigers sent from Russia to Iran's Tehran Zoological Garden in exchange for a pair of Persian leopards were set to be reintroduced in the wild to replace the Turan tigers at the Miankaleh peninsula within the next five years, another region near the Caspian sea. In December 2010, one of the captive Siberian tigers exchanged for the Persian leopards died in Eram Zoo. In 2011, Iran requested four more Siberian tigers and invited conservation experts from Russia to support the reintroduction project to the Caspian Sea coast. Iran received two pairs of Siberian tigers in 2012.

Siberia

The future reintroduction of Siberian tigers is planned as part of the rewilding project at Pleistocene Park in the Kolyma river basin in northern Yakutia (Russia), providing the population of herbivores has reached a size warranting the introduction of large predators such as Asiatic lions, spotted hyenas and Amur leopards.

A Siberian tigress cub was rescued at the Primorsky Krai in February 2012, after losing her mother by poachers, and eventually have been released to the wild in May 2013. In 2015, the very same Siberian tigress gave birth to two wild cubs at Bastak Nature Reserve. She is known as the first Siberian tiger to be in the care of Siberian conservationists and eventually released back into the wild.

Korea

North Korea urged to join Russia and China for the Siberian tigers, after the latest census revealed 562 individuals in total live in the wild. According to the director of the

Amur branch of the World Wildlife Fund (WWF), the northern part of North Korea has suitable conditions for the Amur tigers and analysis of satellite imagery of North Korea has shown this to be the case. An adult female with two cubs has once crossed the border between Russia and North Korea.

Cheetah Reintroduction in India

Reintroduction of the cheetah in India involves the artificial re-establishment of a population of cheetahs into areas where they had previously existed but were hunted into extinction by the British colonial officers and Indian royalty. A part of the reintroduction process is the identification and restoration of their former grassland scrub forest habitats. This is within the scope of the duties of the local forest department of each State, where relocation occurs, through the use of Indian Central Government funding.

Cheetah cubs with dog (India, 1897).

Background

History

A painting depicting Akbar, Mughal emperor of India hunting with locally trapped Indian cheetahs, c. 1602.

Until the 20th century, the Asiatic cheetah was quite common and roamed all the way from Israel, the Arabian Peninsula to Iran, Afghanistan and India. In India, they ranged as far south as the Tirunelveli district of Tamil Nadu. The Asiatic cheetah, also known as the "hunting leopard" in India was kept by kings and princes to hunt gazelle; the Moghul emperor Akbar kept them for hunting gazelle and blackbucks. He was said to have had 1,000 cheetahs at one time for assisting in his royal hunts. Trapping of large numbers of adult Indian cheetahs, who had already learned hunting skills from wild mothers, for assisting in royal hunts is said to be another major cause of the species rapid decline in India as they never bred in captivity with only one record of a litter ever.

Extinction

By the beginning of the twentieth century, the species was already heading for extinction in many areas. The last physical evidence of the Asiatic cheetah in India was three, all shot by the Maharajah Ramanuj Pratap Singh Deo of Surguja in 1947 in eastern Madhya Pradesh, a man also noted for holding a record for shooting 1,360 tigers.

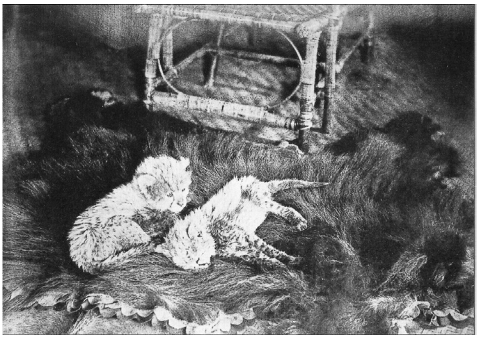
Hunting of blackbuck with Indian cheetah; Drawn by James Forbes in South Gujarat, India. Oriental Memoirs, 1812.

In India in the mid-20th century, prey was abundant, and cheetahs fed on the blackbuck, the chinkara, and sometimes the chital and the nilgai.

...is in low, isolated, rocky hills, near the plains on which live antelopes, its principal prey. It also kills gazelles, nilgai, and, doubtless, occasionally deer and other animals. Instances also occur of sheep and goats being carried off by it, but it rarely molests domestic animals, and has not been known to attack men. Its mode of capturing its prey is to stalk up to within a moderate distance of between one to two hundred yards, taking advantage of inequalities of the ground, bushes, or other cover, and then to make a rush. Its speed for a short distance is remarkable far exceeding that of any other beast of prey, even of a greyhound or kangaroo-hound, for no dog can at first overtake an Indian antelope or a gazelle, either of which is quickly run down by *C. jubatus*, if the start does not exceed about two hundred yards. General McMaster saw a very fine hunting-leopard catch a black buck that had about that start within four hundred yards. It is probable that for a short distance the hunting-leopard is the swiftest of all mammals.

—Blanford writing on the Asiatic Cheetah in India quoted by Lydekker

With the death of the last remaining population of the Asiatic cheetah in India, the species was declared extinct in India; it is the only animal in recorded history to become extinct from India due to unnatural causes. A consequence of the extinction of the cheetahs and subsequently the Indian royalty that prized them was that their grasslands homes came to be controlled, used and managed by local people. “The grasslands faded and diminished under the hooves of a thousand cattle, they were tilled and ploughed until only a few scattered remnants were preserved in the form of wildlife sanctuaries”.



Asiatic cheetah cubs in India, 1897

Reintroduction Efforts

Cloning

During the early 2000s, Indian scientists from the Centre for Cellular and Molecular Biology (CCMB), Hyderabad, proposed a plan to clone Asiatic cheetahs obtained from Iran. India requested Iran to transport one live pair to India. If not possible, Indian scientists requested Iran to allow them to collect some live cells of the cheetah pair in Iran itself, which can then be made into living cell lines.

However, Iran refused saying that it would neither send any cheetahs to India nor would they allow Indian scientists to collect their tissue samples. It is said that Iran wanted an Asiatic lion in exchange for a cheetah and that India was not willing to export any of its Asiatic lions. In 2009, the Indian government contacted Iran again to explore the possibility of Iran supplying cheetahs to help to re-establish their presence on the subcontinent decades after they were hunted to extinction. The Iranian embassy in Delhi had said that its government was in the process of “arranging” talks.

Possible Reintroduction Sites

Currently, wildlife experts have shortlisted three regions which have the potential to support cheetah populations. The Nauradehi Wildlife Sanctuary and Kuno-Palpur Wildlife Sanctuaries in Madhya Pradesh and the Shahgarh bulge landscape in Jaisalmer, Rajasthan have been declared potentially suitable for the reintroduction of the cheetah. The Kuno-Palpur Wildlife Sanctuary in Madhya Pradesh has the potential to hold populations of all four of India's big cats; the Bengal tigers, the Indian leopards, the Asiatic lions and the Asiatic cheetahs, all four of which have co-existed in the same habitats historically for many years, before they were wiped out due to overhunting and habitat destruction. Since the Shahgarh Landscape is fenced along the Indo-Pakistani border region, the addition of more fencing will ensure adequate protection for the cheetah population. The Nauradehi Wildlife Sanctuary (1197km2) is part of a much larger forested landscape (5500km2) which can host the cheetah as well.

At a future date, when sufficient population has built up, other former range habitats in India (after revitalizing them) may also be considered for reintroduction like the Banni grasslands and Desert National Park etc.

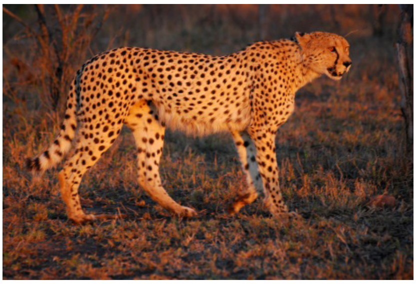
A few wildlife groups have suggested the Moyar river valley in Tamil Nadu's Satyamangalam FD, part of Nilgiri Biosphere Reserve as it is a pristine forest with flourishing population of prey and a good record of conservation. Frederick Augustus Nicholson, the then British Collector has reported to have shot a few individuals near Kothamangalam, Velamundi and Bolampatti (all in NBR). This region is on the leeward side of SW monsoon.

Genetic Sub-species Level Differentiation

The Asiatic cheetah (*Acinonyx jubatus venaticus*) has, for a long time, been *theoretically* classified as a sub-species of the cheetah with the suffix *"venaticus"* applied at the end of its scientific binomial name *Acinonyx jubatus*. However, at a cheetah reintroduction workshop organised in India on 9 September 2009, Stephen J. O'Brien from Laboratory of Genomic Diversity of National Cancer Institute of the US who has in the past conducted numerous prestigious genetic studies - including those on Asiatic lions - said that according to the latest modern genetic studies, it was discovered that the Asiatic cheetah was, in fact, genetically identical to the African cheetah with which it had separated only about 5000 years ago. This was not enough time for a sub-species level differentiation; O'Brien said that in comparison the Asian and African lion subspecies were separated some 100,000 years ago, as was the African and Asian leopard subspecies 169,000 years ago. Cheetah expert Laurie Marker of the Cheetah Conservation Fund and other wildlife experts advised the Indian Government that for reintroduction purposes India should source the cheetah from Africa where they were much more numerous instead of trying to have some removed from the critically endangered low population of about 70 to 110 or so Asiatic cheetahs left in Iran.

India's Union Minister of State for Environment and Forests Jairam Ramesh, chief wildlife wardens of Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh, officials of the environment ministry, cheetah experts from across the globe including Laurie

Marker from Cheetah Conservation Fund, representatives from the Wildlife Institute of India (WII) including Yadvendradev Jhala, and IUCN, an international conservation NGO, among others, participated in a meeting about this issue.



South African cheetah (*Acinonyx jubatus jubatus*)

Asiatic cheetah (*Acinonyx jubatus venaticus*)

Subsequently, in 2011, a much more detailed five-year genetic study involving gathering of DNA samples from the wild, zoos and museums in eight countries was published in *Molecular Ecology (Journal)* on 8 January 2011. This newer study concluded that African and Asiatic cheetahs were in reality genetically very distinct and had in fact separated 32,000 to 67,000 years ago. Sub-species level differentiation had taken place due to longer separation from the African population. The effect of this latest revelation on India's plan to reintroduce cheetahs to the country was left unknown.

Introduction of African Cheetah

As the world's last Asiatic cheetah population in Iran is currently classified as critically endangered, with an estimated total of below 100, the cheetah experts felt that it would not be conducive to disturb it. India is therefore exploring an alternate plan of importing the South African cheetah (*Acinonyx jubatus jubatus*) from some African countries, such as in Namibia where they are in greater abundance, with a view to breeding them in captivity and then setting them free in protected, semi-arid habitats in India.

Since the Asiatic cheetah became extinct in India about half a century ago, suggestions to reestablish the cheetah in India have been ongoing. For this purpose a meeting of International cheetah experts was organized in Gajner, near Bikaner in the Indian state of Rajasthan during September 2009. As per the discussions held at the meeting cheetah experts from around the world favored importing South African cheetahs for the proposed reintroduction in India as against getting them from the world's last remnant population of Asiatic cheetah, also called Iranian cheetah, that only survive in Iran which are currently critically endangered with their entire population estimated to be below 100. International experts including Laurie Marker of Cheetah Conservation Fund, credited with developing cheetah conservation programmes in a number of countries, including Iran, argues that the world's last Asiatic cheetah population in Iran is abysmally low to spare any individuals for reintroduction efforts in India. Stephen J O'Brien, world's leading conservation geneticist and Chief of the Laboratory of Genomic Diversity at the National Cancer Institute, United States, has clarified that there is no significant genetic difference between the African and the Iran's Asiatic cheetah, as per genetic research carried out by him African and Indian cheetahs were only separated just some 5,000 years ago which is not enough for a sub-species level differentiation. "African and Asian cheetahs are similar in nature and have same genetic make-up. So India can have the animal from South Africa if it is not getting from Iran (which has already refused to part with its Asian cheetah)," noted the cheetah genetic expert Stephen J O Brien. At the meeting experts also identified South Africa, Botswana, Kenya, Tanzania and UAE as countries from where the cheetah could be imported for India. "About 5 to 10 animals annually have to be brought to India over a period of 5 to 10 years," recommended another working group, which was formed for exploring sourcing and translocation of the cheetah.

The Ministry of Environment & Forests, Government of India has approved the recommendation for a detailed survey of potential reintroduction sites in the four Indian states of Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh, shortlisted during the consultative meeting. Three more Indian states Karnataka, Andhra Pradesh and Maharashtra are being also considered. This survey will form the basis for the roadmap of reintroduction of cheetah in India, and will be carried out by the Wildlife Institute of India (WII),.

Current Status

The Ministry of forests and environment of India is now hammering out the details of the cheetah conservation plan. As a first step, a two-day seminar of technical experts on cheetahs was held in Gajner from 9 September 2009. Experts on cheetah, including Divyabhanusinh Chavda and M K Ranjitsinh presented their papers on how to go about bringing cheetahs to India.

The initial plans were to bring the cheetahs to Gajner Wildlife Sanctuary. "We want to set up a breeding ground for the cheetahs and Gajner seems to fit the bill perfectly. Thereafter, they will be transported to various states," he added.

India is also in talks with the Islamic Republic of Iran over the possibility of sending a pair of Asiatic cheetahs to India. It is said that Iran wanted an Asiatic lion in exchange for a cheetah and that India wasn't ready to export any of its Asiatic lions. The Iranian embassy in Delhi said that its government was in the process of "arranging" talks.

The Union Minister of State for Environment and Forests Jairam Ramesh said that African cheetahs could be brought to India within three years having just returned from a trip to South Africa, one of the potential source-habitats of cheetahs to be moved to India.

The Wildlife Institute of India is spearheading the project, and will unveil a road map and destination for the African cheetahs – possible options are in Rajasthan, Madhya Pradesh and Gujarat – by the end of May.

Kuno Palpur and Nauradehi Sancturies in Madhya Pradesh and Shahgarh landscape in Jaisalmer in Rajasthan have been selected in by the Wildlife Institute of India as most suitable sites for the reintroduction project.

Plans on Hold

As of May 2012 the Indian Supreme Court has put the project of importing cheetahs from Africa and reintroducing them in India on hold. Some Conservationists have been fighting a legal battle in Indian Supreme Court to get the Indian State Government of Gujarat to break its monopolizing of wild Asiatic lions and release a few overpopulated prides of Asiatic lions spilling out of Gir National Park for reintroduction in the Kuno Wildlife Sanctuary in the neighbouring Indian State of Madhya Pradesh which was prepared for them after relocating over 24 villages out of the forest. In the past, for last two decades the State Government of Gujarat had concocted every possible reason to maintain its monopoly on wild Asiatic lions and the tourism revenue generated by them and of recent Gujarat's legal council had put forward the argument that Kuno Wildlife Sanctuary is being used for the introduction of African cheetah which might take several years to fully settle down and repopulate the area and hence reintroduction of Asiatic lions should only be done after that, this scared the conservationists that Gujarat will use this pretext to delay the reintroduction of native Asiatic lions by many more decades using the cheetah argument. Indian Supreme court has taken note of the arguments put forth by some Indian conservationists that importing African cheetah for reintroduction in India is misguided as it is against IUCN reintroduction guidelines and no clearance had been sought from India's National Board for Wildlife. The Indian Supreme Court has put the project on hold till further notice asking for clearance from India's National Board for Wildlife, meantime it has fast tracked the case for the re-introduction of Asiatic lions to Kuno Wildlife Sanctuary and is hearing it every Monday.

Senior advocate PS Narasimha, court-appointed adviser and the amicus curiae in the Asiatic lion relocation case in India's Supreme Court, filed an application seeking a stay on the implementation of African cheetah reintroduction project in India. The Indian Supreme court granted the stay and the matter has been scheduled for further hearing in July 2012 after the court returns from vacation. During its hearings, the Bench was informed that India's Ministry of Environment and Forests (MoEF) has decided to introduce the South African cheetah (*Acinonyx jubatus jubatus*) from Namibia into Kuno Wildlife Sanctuary in the Indian state of Madhya Pradesh, the same proposed habitat being developed as the second home for the translocation of Asiatic lions from Gir Wildlife Sanctuary in the neighbouring Indian state of Gujarat which did not want to shift any Asiatic lions out of the state. Narasimha said the proposal for reintroduction of African cheetah "has not been either placed before the Standing Committee of India's National Board for Wildlife, nor has there been a considered decision taken in this regard". He stated in an application that "scientific studies show that the African Cheetahs and Asian Cheetahs are completely different, both genetically and also in their characteristics" and the reintroduction of African cheetah in India was also against the International Union for the Conservation of Nature (IUCN) guidelines on translocation of wildlife species. "In fact, the (IUCN) guidelines categorically warn against the introduction of alien or exotic species. The African Cheetah obviously never existed in India. Therefore, it is not case of intentional movement of an organism into a part of its native range," the application stated. Asiatic cheetah became extinct in India in the 1950s, In the past, India's last recorded cheetah in the wild was said to have been shot in the Rewa area of Madhya Pradesh in the late 1940s. It was mentioned that the introduction of alien or exotic species is universally shunned by wildlife experts and "in fact countries such as South Africa, Australia are spending huge amount of funds to eradicate and remove exotic wildlife species from wilderness areas or wild habitats". Narasimha also sought a direction of India's Ministry of Environment and Forests (MoEF) to produce before the apex court all relevant records and decisions relating to introduction of cheetah. He said the Indian cheetah in genetic composition is a different animal than the African cheetah and a different sub species altogether and "therefore one cannot be introduced in place of the other". Conservationists say fewer than 100 of the critically endangered Asiatic cheetah subspecies remain only in Iran, roaming the central deserts. The vast majority of the 10,000 cheetahs left in the world are in Africa.

Arabian Oryx Reintroduction

The Arabian oryx (*Oryx leucoryx*), also called the white oryx, was extinct in the wild as of 1972, but was reintroduced to the wild starting in 1982. Initial reintroduction was primarily from two herds: the "World Herd" originally started at the Phoenix Zoo in 1963 from only nine oryx and the Saudi Arabian herd started in 1986 from private collections and some "World Herd" stock by the Saudi National Wildlife Research Center (NWRC). As of 2009 there have been reintroductions in Oman, Saudi Arabia, Israel, the United Arab Emirates, and Jordan, and as of 2013 the IUCN Red List classifies the species as vulnerable.

Arabian oryx at Chay Bar Yotvata, Israel

Decline of a Species

The Arabian oryx was known to be in decline since the early 1900s in the Arabian Peninsula. By the 1930 there were two separate populations isolated from each other. In 1960, Lee Talbot reported that Arabian oryx appeared to be extinct in its former range along the southern edge of Ar-Rub' al-Khali. He believed that any oryx still existing would be exterminated within the next few years and recommended that a captive breeding program be started to save the species. Michael Crouch, then Assistant Adviser in the Eastern Aden Protectorate, drew attention to the fact that each spring, small groups of oryx still emerged onto the gravel plains in the northeast corner of the Protectorate, where he thought a capture attempt would be possible.

Operation Oryx

Operation Oryx was a program of the Phoenix Zoo and the Fauna and Flora Preservation Society of London (now Fauna and Flora International), with financial help from the World Wide Fund for Nature. One of the first captive breeding programs at any zoo, this program had the specific goal of saving and then reintroducing Arabian oryx in the wild.

The initial plan of the Fauna and Flora Preservation Society was to establish a herd in Kenya where another species of oryx already lived and flourished. The Kenyan plan was dropped because of an outbreak of hoof-and-mouth disease, and the oryx destined for Kenya were shipped to the Phoenix Zoo instead.

Although in hindsight we know that there were actually quite a few potential Arabian oryx in private collections. For instance, the Arabian reintroduction was started with 57 Arabian oryx from the collection of King Khalid bin Abdul Aziz in Ath-Thumamah, this was not known in 1962, when only 16 oryx were located as possible breeding stock.

There were originally four individuals captured and seven donated for this project. The four were captured in Aden (now Yemen) near the border of Oman by an expedition led by the late Major Ian Grimwood, then chief game warden of Kenya, with help from Manahil and Mahra tribesmen. One male from this group later died of capture stress. The seven donated oryx were: one from the London Zoo, two from Sheikh Jaber Abdullah al-Sabah, and two pairs from the collection of King Saud bin Abdul Aziz. One of the oryx from Sheikh Jaber Abdullah al-Sabah died before delivery as well, leaving nine oryx to start the "World Herd."

Five Arabian oryx were delivered to the Phoenix Zoo in 1963 (four in June and one in September). A baby was born to the herd in October 1963 from a conception en route, and another was born in the spring of 1964, bringing the starting population of the Phoenix Zoo herd to seven. The four oryx donated by King Saud arrived at the Phoenix Zoo in July 1964, bringing the population of the "World Herd" to 11.

The breeding program at the Phoenix Zoo was very successful, and the zoo celebrated its 225th Arabian oryx birth in 2002. From Phoenix, individuals were sent to other zoos and parks (including the San Diego Wild Animal Park) to start their herds. Most of the Arabian oryx in the wild today have ancestors from the Phoenix Zoo.

Reintroductions

Reintroductions started in 1982 in Oman. As of 2009 there have been reintroductions in Oman, Saudi Arabia, Israel, the United Arab Emirates, and Jordan. At this time, populations in the United Arab Emirates and Jordan are still not considered in the International Union for Conservation of Nature (IUCN) Red List wild oryx count. The population in Oman is still receiving supplementary forage, and the introduction into Jordan was after the last update of the Red List.

Oman

By 1980 the number of Arabian oryx in captivity had increased to the point that reintroduction to Oman was attempted from the San Diego Wild Animal Park to Jaaluni in the Jiddat al-Harasis. The oryx were initially kept in large pens outdoors, but were released to the wild on January 31, 1982 in the Omani Central Desert and Coastal Hills.

These oryx became the core of the Oman herd in the wild, though there were several other releases of captive bred animals over the next two decades. The area of their release became the Arabian Oryx Sanctuary.

On June 28, 2007, Oman's Arabian Oryx Sanctuary was the first site to be removed from the UNESCO World Heritage List. UNESCO cited the Omani government's decision to open 90% of the site to oil prospecting as the main reason for this decision. The Arabian oryx population on the site has been reduced from 450 oryx in 1996 to only 65 in 2007, mostly due to poaching and illegal live capture. There are now fewer than four breeding pairs left on the site.

Saudi Arabia

Organized captive breeding of the Arabian oryx in Saudi Arabia began in April 1986, when 57 oryx from the farm of the late King Khalid bin Abdul Aziz in Ath-Thumamah (now the King Khalid Wildlife Research Center or KKWRC) were brought to the National Wildlife Research Center (NWRC) near At-Ta'if.

Between the initial 1986 founding and 1996, 33 additional oryx (including some from the "World Herd") have been introduced to the founder generation of Arabian oryx at the NWRC. Since 1996, all additions to the population have been through births.

Due to an outbreak of *Mycobacterium bovis* (bovine tuberculosis) in the founder generation, a "buffer generation" was introduced in the herd. Since then, calves produced by the founder herd are removed from their dam immediately after birth and hand-reared. These hand-reared second generation oryx are regularly tested for tuberculosis and a variety of other pathogenic agents, and join the breeding nucleus only when tests are consecutively negative. After breeding, they produce the third generation of oryx, which are tuberculosis free and mother-reared, and of which more than 80% are reintroduced into the wild.

Reintroduction of a wild population began in 1995 in the 'Uruq Bani Ma'arid Protected Area. The reserve covers about 12,000 km^2 (4,600 sq mi) at the western edge of the Rub'al-Khali or "Empty Quarter". As of 2009, the IUCN Red List estimates the oryx population on this reserve at 160 individuals.

A free ranging herd was established in the newly created Mahazat as-Sayd Protected Area in 1989. This 2,244 km^2 (866 sq mi) fenced reserve is home to reintroduced oryx, gazelle and the houbara bustard. As of 2009, the IUCN Red List estimates the oryx population on this reserve at about 800 individuals. There is currently some debate about whether animals in this reserve should be considered "wild."

Israel

In Israel the reintroduction program was established in 1978 when four pairs of Arabian oryx were purchased. At this time the IUCN Redbook reported wild populations totaling 90-100 animals in 3 locations in Northern Arava and the Negev Desert. As of 2014 there are there are around 130 animals in the Aravah, and in 2013 they began to spread to the central Negev and the population keeps increasing. In addition to the natural population increase, every year around six animals are released to the wild in Israel. Israel is the only country in which the Arabian oryx was reintroduced where poaching prohibition can be enforced, and because of this the Israeli population grows annually. Apart from the wild oryx population in Israel, there are few dozen oryx in the Yotvata Hai-Bar Nature Reserve, a few breeding couples in the Jerusalem Biblical Zoo and a small herd in the Ramat Gan Safari. The reintroduction of oryx in Israel is one of a few successful programs reintroducing animals into nature in Israel; others include the introduction of the Persian onager (a proxy for the extinct Syrian onager), and the very successful reintroduction of Persian fallow deer.

The United Arab Emirates

In the early 1960s, the late Sheikh Zayed bin Sultan Al Nahyan directed the capture of two breeding pairs of the Arabian oryx for the nucleus of a captive-breeding program in Al Ain. In 2007 the United Arab Emirates started releasing animals into Umm Al Zumul. As of 2009 there have been about 100 animals released.

As part of this initiative, a similar program is being developed to reintroduce this extinct species into its natural habitats in Yemen and Iraq.

Since March 1999, Abu Dhabi has been host to an inter-governmental body known as The Coordinating Committee for the Conservation of the Arabian Oryx, which oversees the coordination of conservation efforts for this species within the Arabian Peninsula. In 2012, GSCAO carried out an Arabian Oryx Disease Survey which was funded by the Environment Agency – Abu Dhabi (EAD), in the range states.

Jordan

The reintroduction project for Jordan began when the Environment Agency - Abu Dhabi (EAD) and the Al Aqaba Special Economic Zone Authority signed a sponsorship agreement in April 2007. Under this agreement, EAD is sponsoring the million three-year project which includes reintroduction of the Arabian oryx into the Wadi Rum Protected Area, rehabilitating the habitat, and helping local residents to improve their living standards.

Twenty oryx (12 males and 8 females) were released into the Wadi Rum Protected Area in July 2009.

Current Status

In 1986, as a result of the reintroduction efforts, the IUCN re-listed the Arabian oryx from extinct in the wild to endangered. By 2009, the Arabian oryx was protected by law in all areas where it appears.

In June 2011, the Arabian oryx was re-listed as vulnerable by the IUCN Red List. The IUCN estimates there are more than 1000 Arabian oryx in the wild, with 6000-7000 held in captivity worldwide in zoos, preserves, and private collections. Some of these are in large fenced enclosures (free-roaming), including those in Syria (Al Talila), Bahrain, Qatar, and UAE. This is the first time the IUCN has re-classified a species as vulnerable after it had been listed as extinct in the wild. The Arabian oryx is also listed in CITES Appendix I.

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We would like to thank the editorial team for lending their expertise to make the book truly unique. They have played a crucial role in the development of this book. Without their invaluable contributions this book wouldn't have been possible. They have made vital efforts to compile up to date information on the varied aspects of this subject to make this book a valuable addition to the collection of many professionals and students.

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The publisher and the editorial board hope that this book will prove to be a valuable piece of knowledge for students, practitioners and scholars across the globe.

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